

Figure 3-2. Anadromous fish distribution in the Nushagak and Kvichak River watersheds. Documented salmon use indicates that at least one Pacific salmon species (Coho, Chinook, Sockeye, Chum, or Pink) has been documented at the most upstream point in the channel, based on the Anadromous Waters Catalog (Giefer and Graziano 2022).

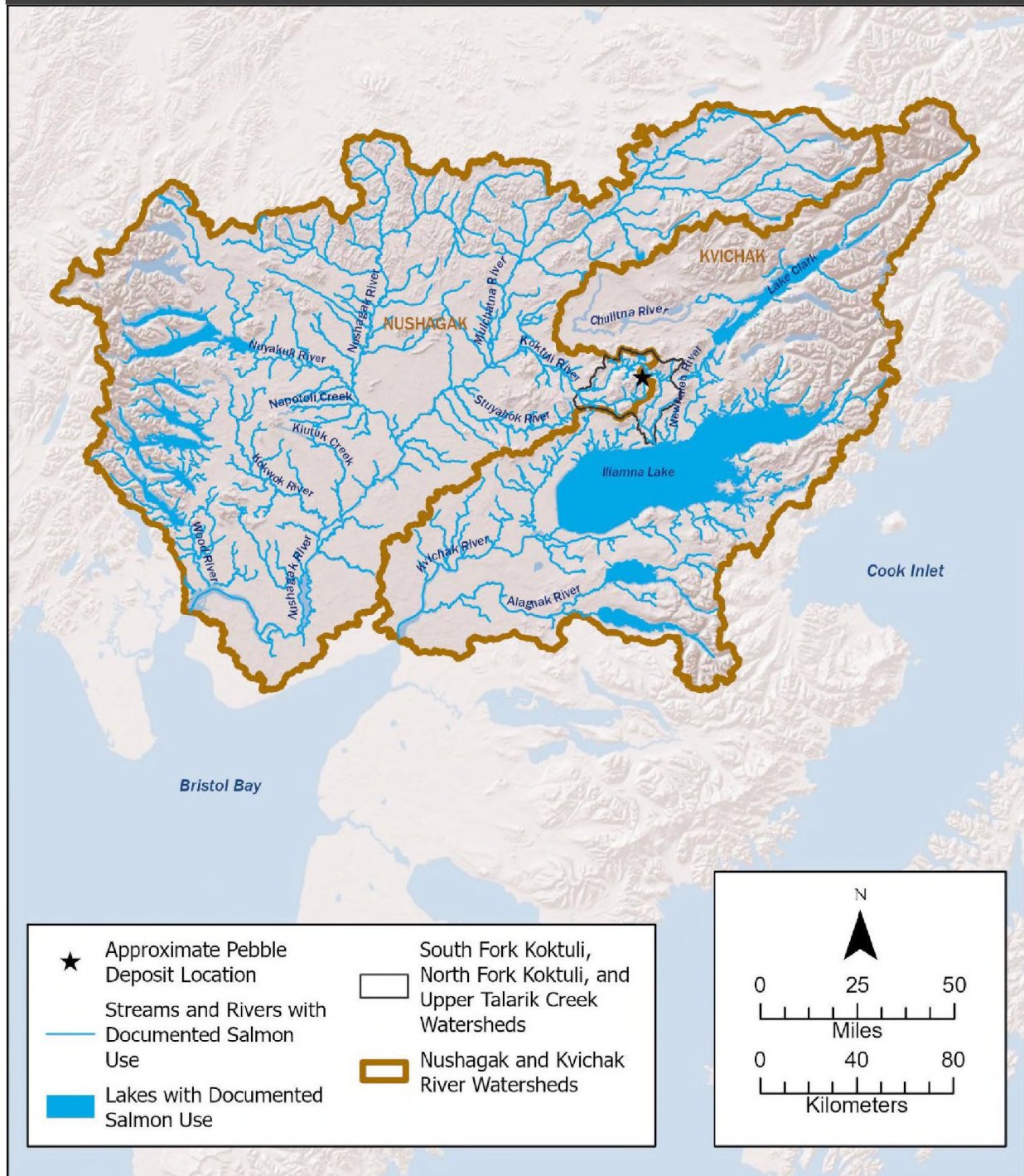


Figure 3-3. Rainbow Trout, Dolly Varden, and Arctic Grayling occurrence in the Nushagak and Kvichak River watersheds. Designation of species presence is based on the Alaska Freshwater Fish Inventory (ADF&G 2022a). Note that points shown on land actually occur in smaller streams not shown on this map.

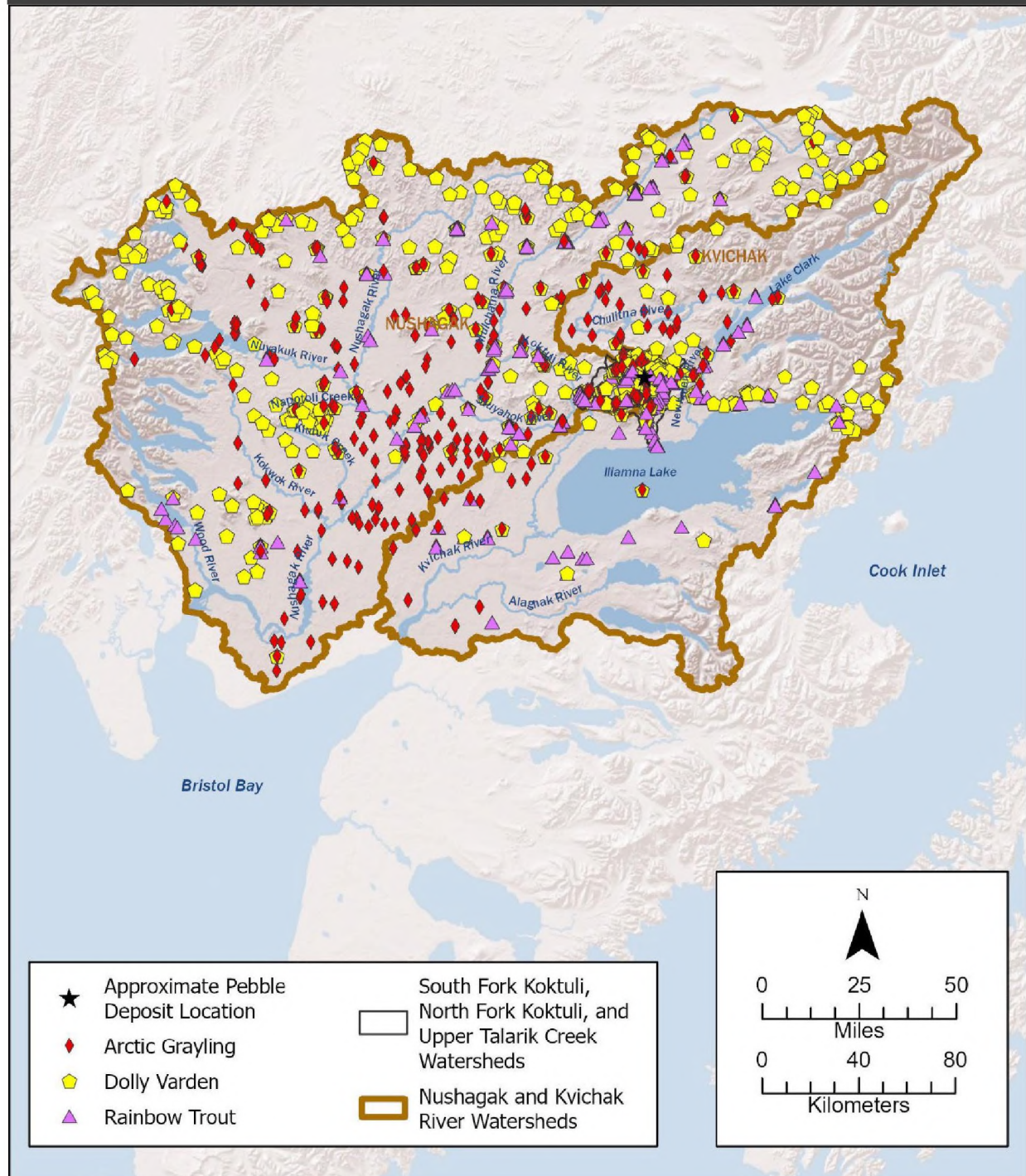
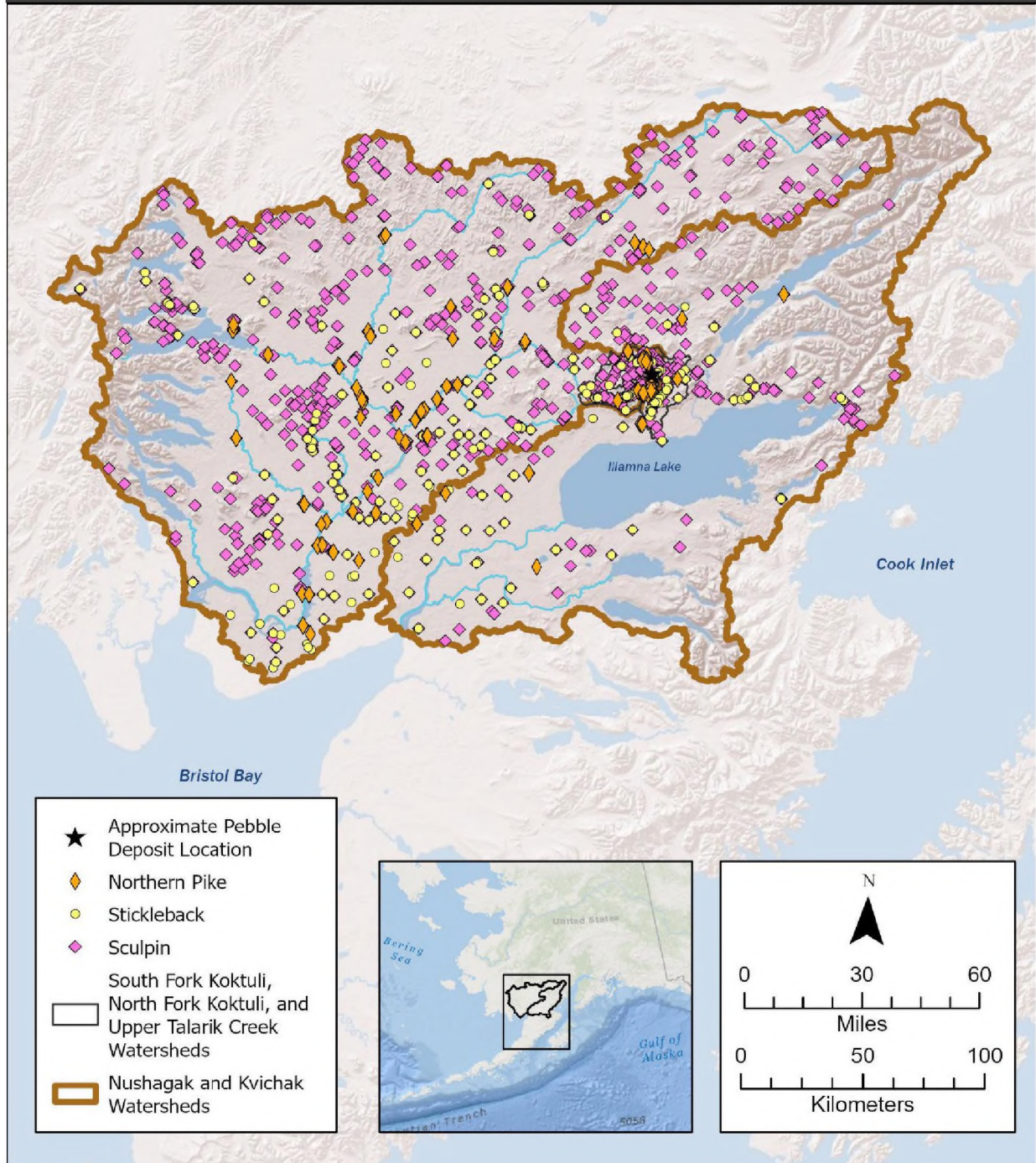


Figure 3-4. Northern Pike, stickleback, and sculpin occurrence in the Nushagak and Kvichak River watersheds. Designation of species presence is based on the Alaska Freshwater Fish Inventory (ADF&G 2022a). Note that points shown on land actually occur in smaller streams not shown on this map.



3.3.2.2 South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek Watersheds

This section highlights the abundance and diversity of fish resources in the SFK, NFK, and UTC watersheds, particularly in terms of Pacific salmon. The important relationship between the region's aquatic habitats and its fish populations—and the resulting ecological value of this relationship—is discussed in greater detail in Section 3.3.3.

Summer fish distributions in the SFK, NFK, and UTC watersheds have been sampled over several years (PLP 2011: Chapter 15, PLP 2018a: Chapter 15). The catalogued distributions of the five Pacific salmon species (Coho, Chinook, Sockeye, Chum, and Pink), resident Rainbow Trout, Dolly Varden (both anadromous and non-anadromous forms are present), and Arctic Grayling in these watersheds are shown in Figures 3-5 through 3-10. In addition, Arctic-Alaskan Brook Lamprey, Northern Pike, Humpback Whitefish, Least Cisco, Round Whitefish, Burbot, Threespine Stickleback, Ninespine Stickleback, and Slimy Sculpin occur in these watersheds (Table 3-5) (ADF&G 2022a). Summary information about these species is provided in Table 3-3; more detailed information on distributions, abundances, habitats, life cycles, predator-prey relationships, and harvests is provided in Appendix B of EPA (2014) and Section 3.6 of USACE (2020a).

Table 3-5. Documented fish species occurrence in the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek watersheds.

Species ^a	Number of Unique Sites ^b
Humpback Whitefish	2
Least Cisco	3
Round Whitefish	3
Coho Salmon	525
Chinook Salmon	183
Sockeye Salmon	102
Chum Salmon	7
Rainbow Trout	110
Dolly Varden ^c	682
Arctic Grayling	199
Arctic-Alaskan Brook Lamprey ^c	4
Northern Pike	74
Burbot	2
Threespine Stickleback	32
Ninespine Stickleback	67
Unspecified stickleback species	27
Slimy Sculpin	533
Unspecified sculpin species	226

Notes:

^a This is not a complete list of species found in the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek watersheds, because it is based only on the Alaska Freshwater Fish Inventory (ADF&G 2022a); for example, Pink Salmon are only listed in the Anadromous Waters Catalog (Giefer and Graziano 2022).

^b Number of unique sample sites for each species (i.e., number of sample sites where at least one life stage of the species was found).

^c Juveniles of these two species, which are the most commonly encountered life stage in these watersheds, are indistinguishable. Both species are present in the watersheds, but it is possible that all documented occurrences are for one of these species.

Source: Alaska Freshwater Fish Inventory (ADF&G 2022a).

Of the 667 stream miles (1,073 km) that have been mapped in the SFK, NFK, and UTC watersheds, 201 miles (323 km) or 30 percent have been documented to contain anadromous fishes (Table 3-6; see Appendix B for discussion of why this likely represents a significant underestimation of actual anadromous waters). Coho Salmon have the most widespread distribution of the five salmon species in the three watersheds and make extensive use of mainstem and tributary habitats, including headwater streams (Figure 3-5). Chinook and Sockeye salmon have been documented throughout mainstem reaches of the three watersheds, as well as several tributaries (Figures 3-6 and 3-7). The distributions of Chum and Pink salmon are generally restricted to mainstem reaches where spawning and migration have been documented. Chum Salmon have been found in all three watersheds, whereas Pink Salmon, at very low numbers, have been reported only in the lowest section of UTC and in the Koktuli River below the confluence of the SFK and NFK (Figures 3-8 and 3-9). Rainbow Trout have been collected at many mainstem and several tributary locations, especially in UTC (Figure 3-10). Dolly Varden are found throughout the three watersheds, with fish surveys indicating that they are commonly found in the smallest streams (i.e., first-order tributaries) (Figure 3-10). Arctic Grayling are also found throughout the three watersheds, particularly in the SFK headwaters (Figure 3-10).

Table 3-6. Total documented anadromous fish stream length and stream length documented to contain different salmonid species in the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek watersheds.

	South Fork Koktuli River (miles)	North Fork Koktuli River (miles)	Upper Talarik Creek (miles)	Total (miles)
Total mapped streams ^a	194	209	264	667
Total anadromous fish streams ^b	60	65	76	201
By species				
Chinook Salmon	38	43	39	120
Chum Salmon	23	20	28	71
Coho Salmon	59	64	76	199
Pink Salmon	0	0	4	4
Sockeye Salmon	40	29	49	119

Notes:

^a From the National Hydrography Dataset (USGS 2021b).

^b From the Anadromous Waters Catalog (Giefer and Graziano 2022).

Figure 3-5. Reported Coho Salmon distribution in the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek watersheds. "Present" indicates the species was present but life-stage use was not determined; "spawning" indicates spawning adults were observed; and "rearing" indicates juveniles were observed. Present, spawning, and rearing designations are based on the Anadromous Waters Catalog (Gieffer and Graziano 2022).

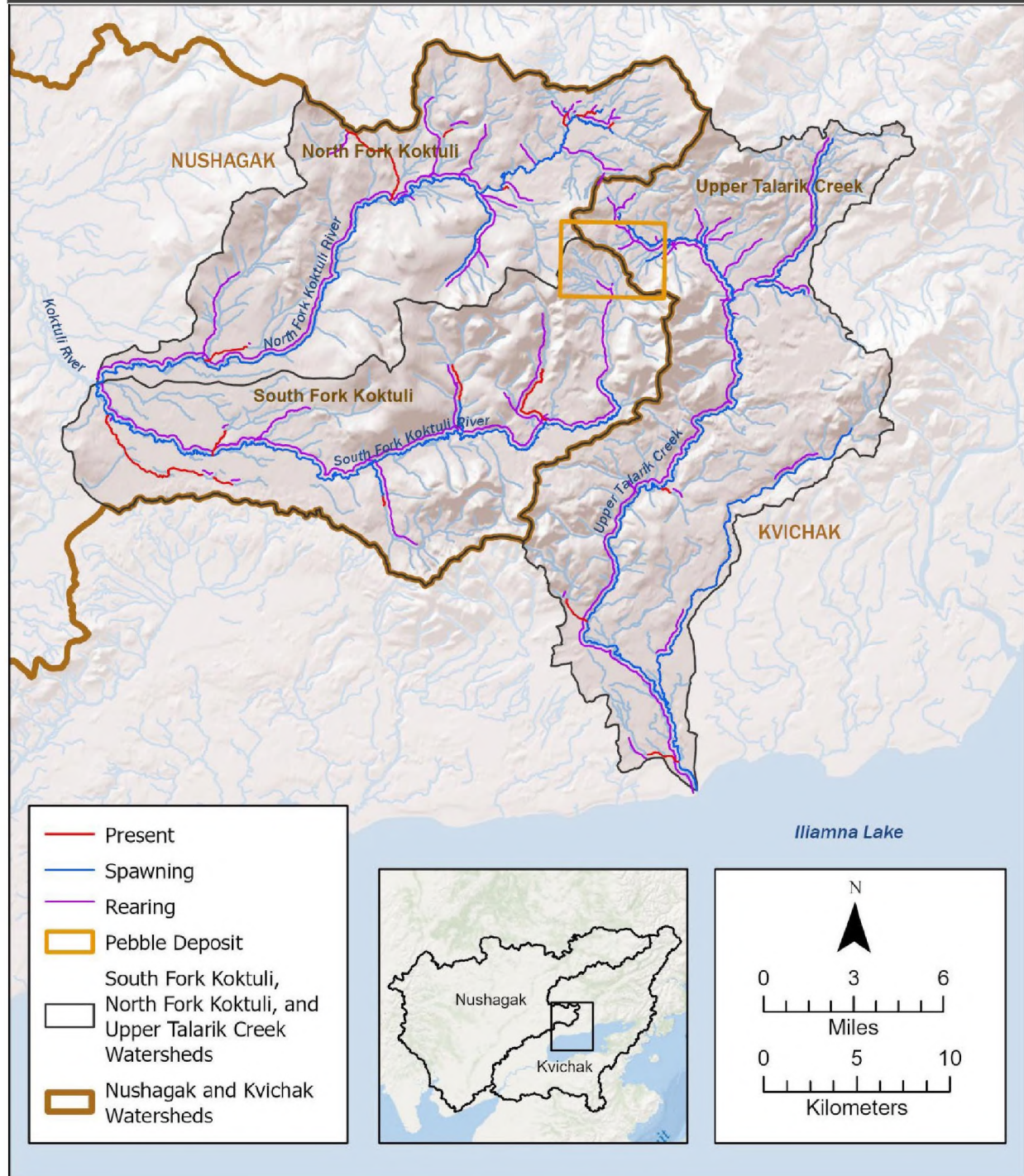


Figure 3-6. Reported Chinook Salmon distribution in the South Fork Kaktuli River, North Fork Kaktuli River, and Upper Talarik Creek watersheds. “Present” indicates the species was present but life-stage use was not determined; “spawning” indicates spawning adults were observed; and “rearing” indicates juveniles were observed. Present, spawning, and rearing designations are based on the Anadromous Waters Catalog (Gieffer and Graziano 2022).

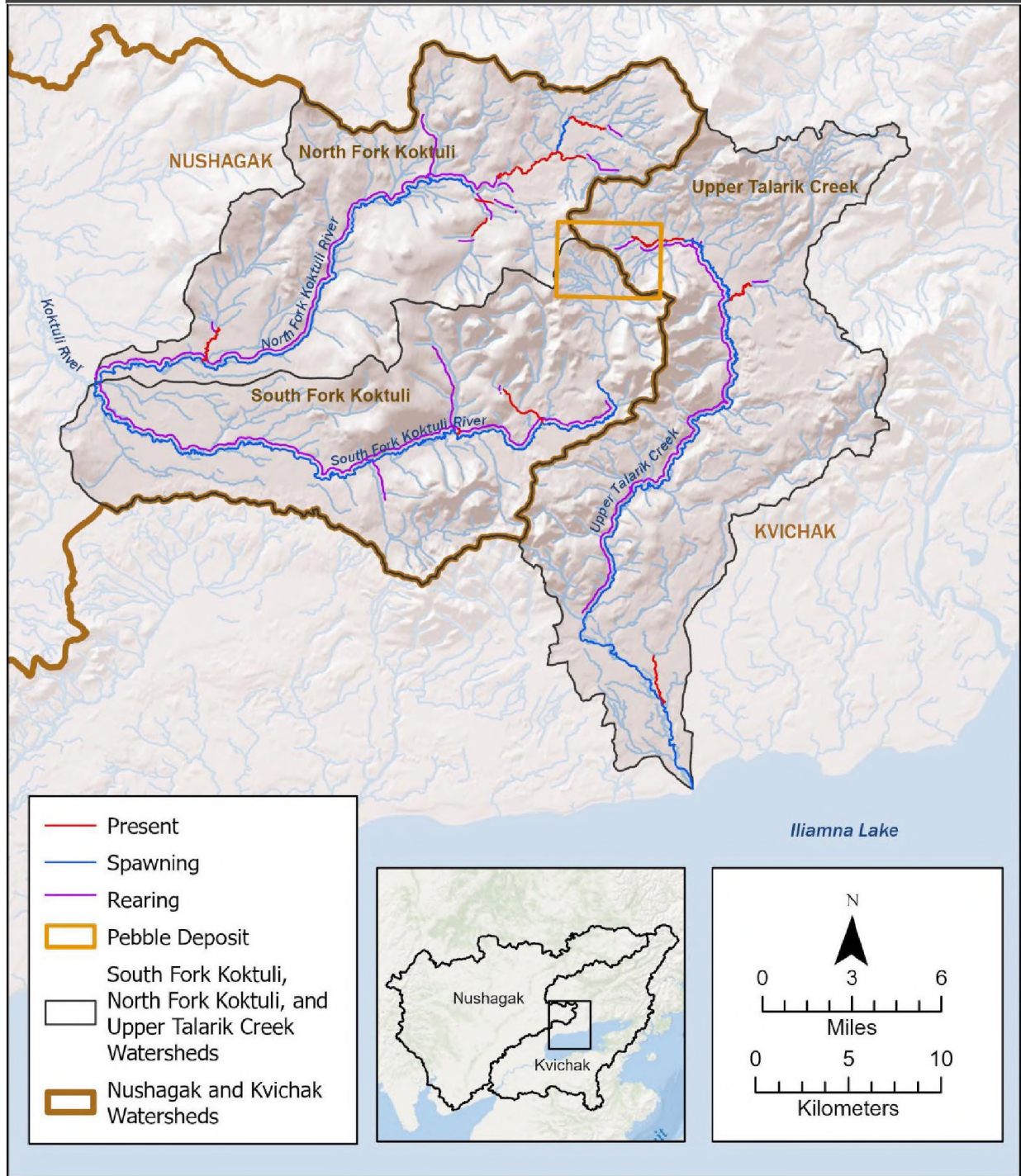


Figure 3-7. Reported Sockeye Salmon distribution in the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek watersheds. “Present” indicates the species was present but life-stage use was not determined; “spawning” indicates spawning adults were observed; and “rearing” indicates juveniles were observed. Present, spawning, and rearing designations are based on the Anadromous Waters Catalog (Gieffer and Graziano 2022).

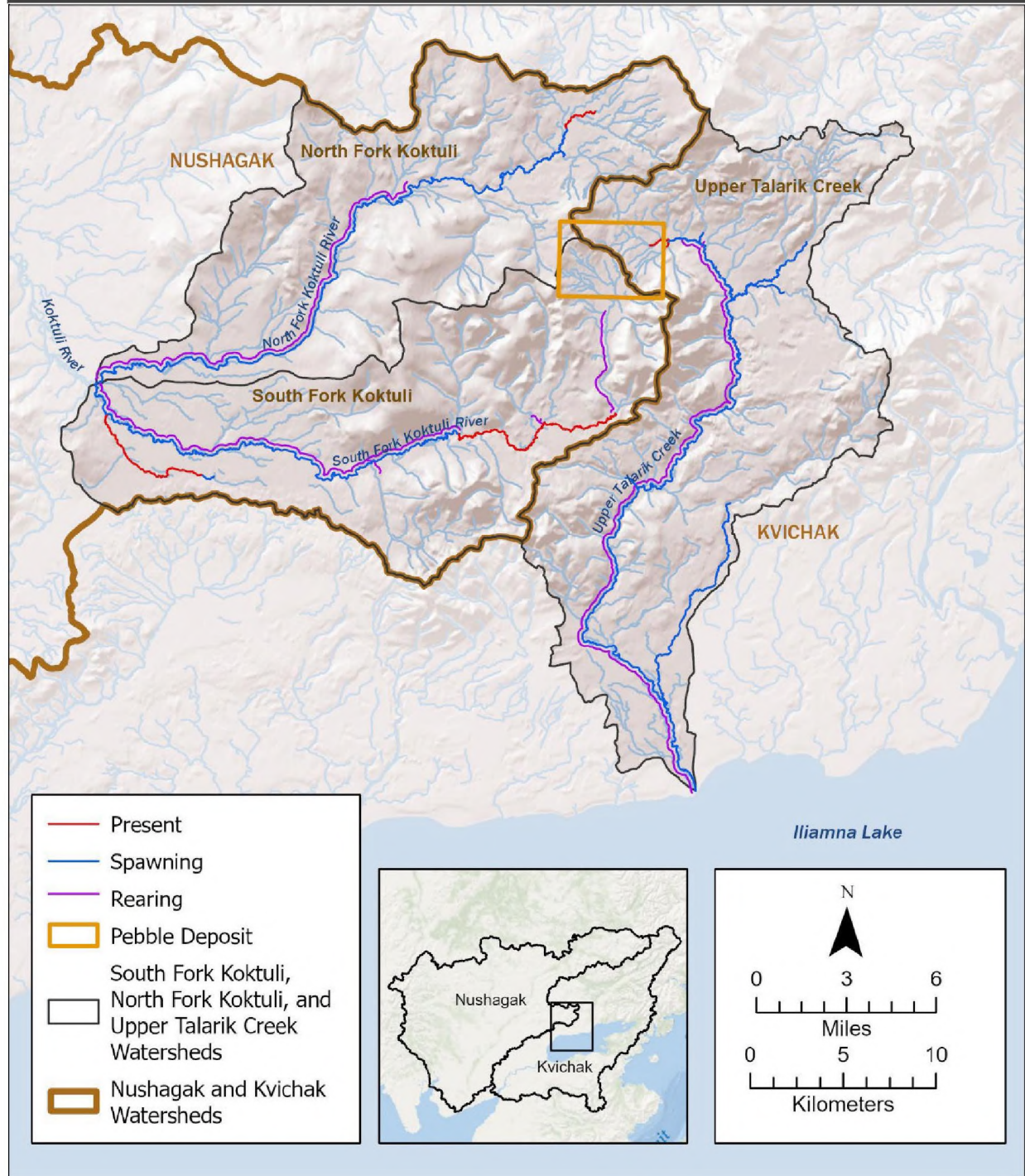


Figure 3-8. Reported Chum Salmon distribution in the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek watersheds. “Present” indicates the species was present but life-stage use was not determined; “spawning” indicates spawning adults were observed; and “rearing” indicates juveniles were observed. Present, spawning, and rearing designations are based on the Anadromous Waters Catalog (Gieffer and Graziano 2022).

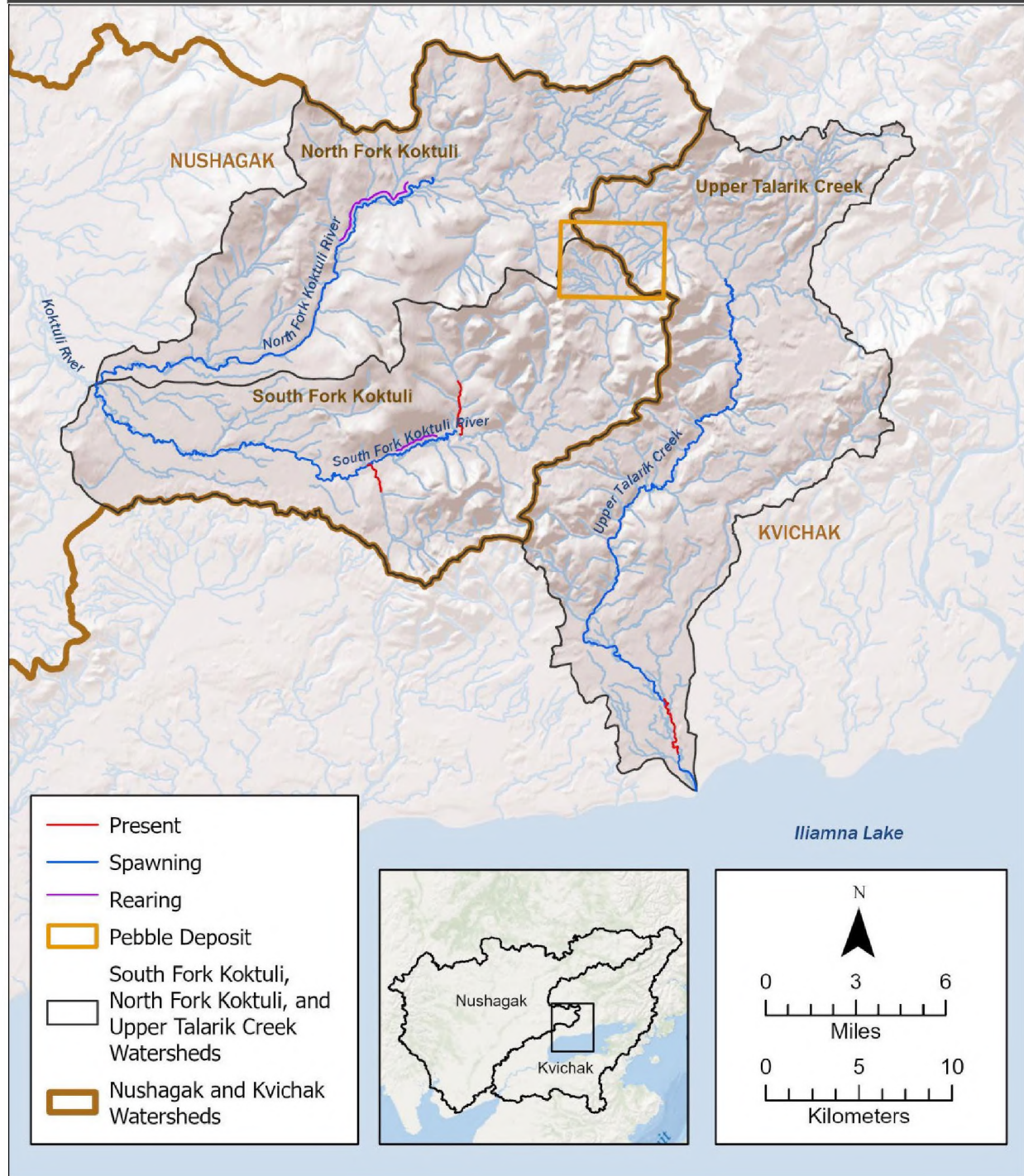


Figure 3-9. Reported Pink Salmon distribution in the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek watersheds. "Present" indicates the species was present but life-stage use was not determined; "spawning" indicates spawning adults were observed; and "rearing" indicates juveniles were observed. Present, spawning, and rearing designations are based on the Anadromous Waters Catalog (Gieffer and Graziano 2022).

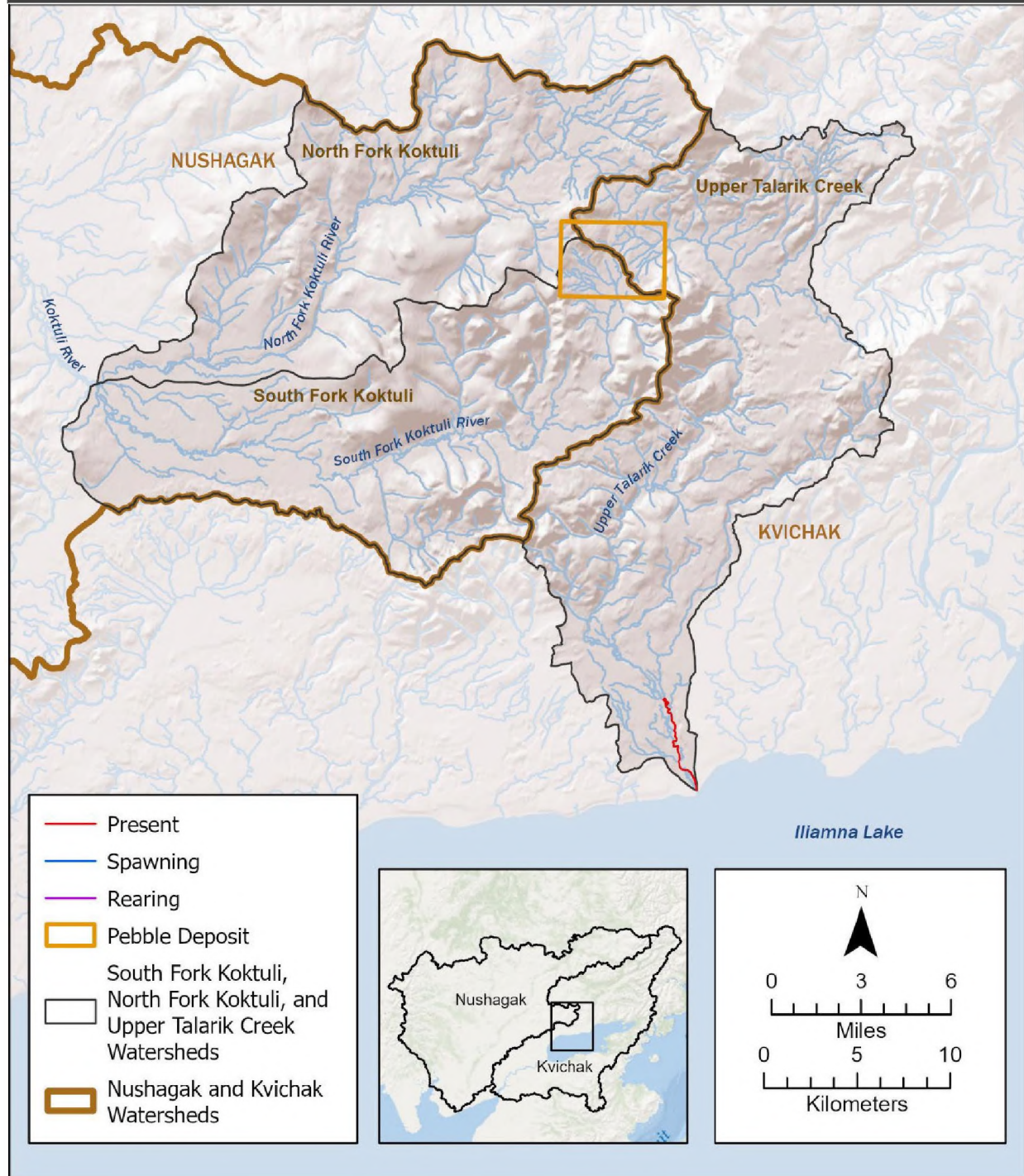
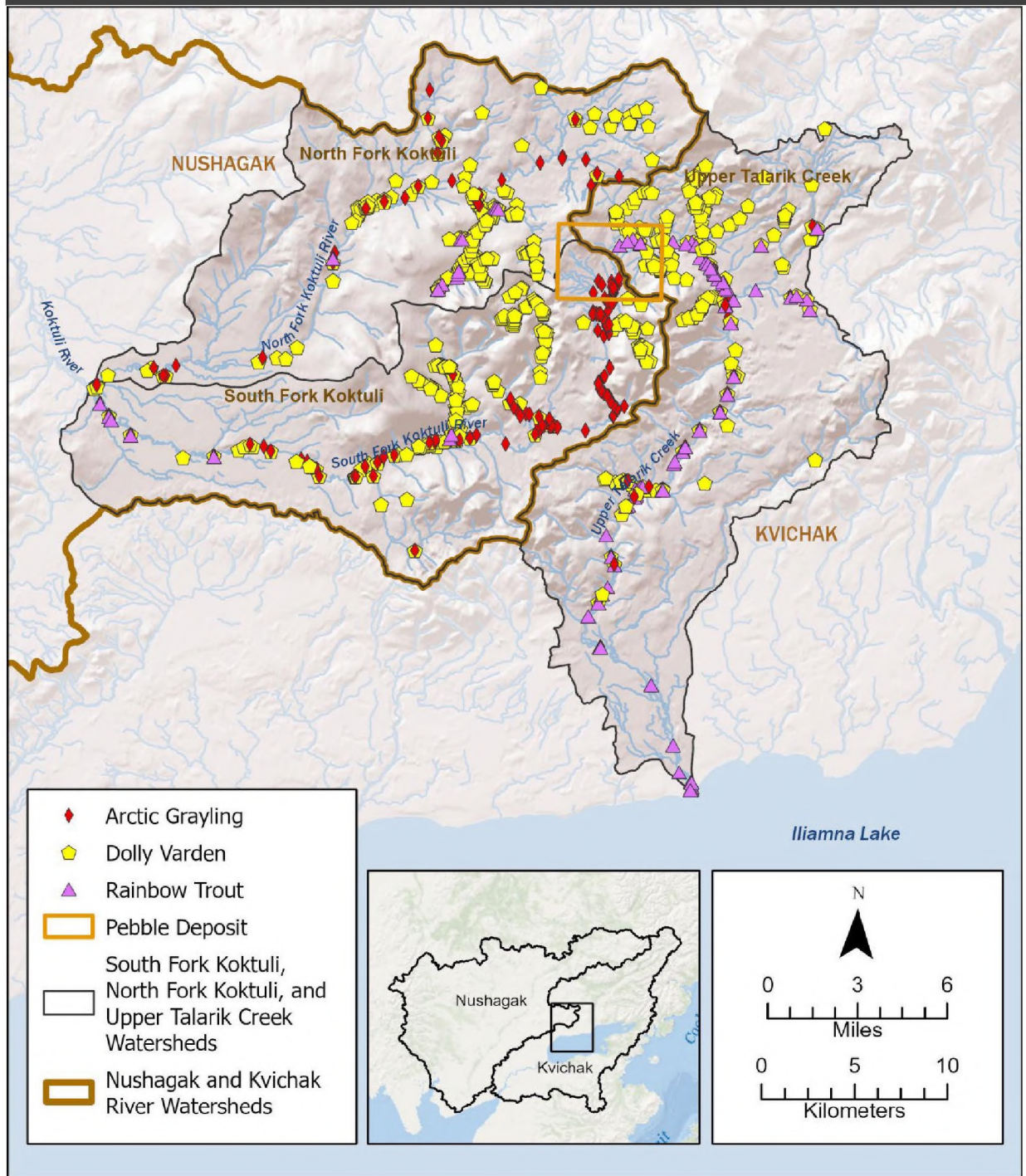


Figure 3-10. Rainbow Trout, Dolly Varden, and Arctic Grayling occurrence in the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek watersheds. Designation of species presence is based on the Alaska Freshwater Fish Inventory (ADF&G 2022a).



Index estimates of relative spawning salmon abundance in the SFK, NFK, and UTC watersheds are available for Sockeye, Coho, Chinook, and Chum salmon. Both ADF&G and PLP have conducted aerial index counts of spawning salmon at different points in time. This type of survey is used primarily to track variation in run size over time. Survey values tend to underestimate true abundance: for example, USACE (2020a: Section 3.24) states that aerial surveys capture only an average of 18 percent of total abundance. This underestimation occurs for several reasons. An observer in an aircraft is not able to count all fishes in dense aggregations or those concealed under overhanging vegetation or undercut banks, and only a fraction of the fishes that spawn at a given site are present at any one time (Bue et al. 1998, Jones et al. 2007). Weather, water clarity, and other factors that influence fish visibility can also contribute to underestimates. In addition, surveys intended to capture peak abundance may not always do so. For example, aerial surveys counted, on average, only 44 percent of the Pink Salmon counted by surveyors walking the same Prince William Sound spawning streams (Bue et al. 1998). Peak aerial counts of Pink Salmon in southeastern Alaska are routinely multiplied by 2.5 to represent more accurately the number of fishes present at the survey time (Jones et al. 2007). Helicopter surveys of Chinook Salmon on the Kenai Peninsula's Anchor River over 5 years counted only 5 to 10 percent of the fishes documented by a concurrent sonar/weir counting station (Szarzi et al. 2007).

ADF&G conducts aerial index counts that target peak Sockeye Salmon spawning periods on UTC and peak Chinook Salmon spawning periods on the Kaktuli River system. Sockeye Salmon counts have been conducted in most years since 1955 (Morstad 2003), and Chinook Salmon counts in most years since 1967 (Dye and Schwanke 2009). Between 1955 and 2011, Sockeye Salmon counts in UTC ranged from 0 to 70,600, with an average of 7,021 over 49 count periods (Morstad pers. comm.). Between 1967 and 2009, Chinook Salmon counts in the Kaktuli River system ranged from 240 to 10,620, with an average of 3,828 over 29 count periods (Dye and Schwanke 2009). The mean aerial count of Chinook Salmon in the Kaktuli River represents nearly one-quarter of the mean total for the entire Nushagak-Mulchatna watershed (Dye and Schwanke 2009). Thus, the Nushagak River is the largest producer of Chinook Salmon in the Bristol Bay watershed, and the Kaktuli River is the largest producer of Chinook Salmon in the Nushagak River watershed.

PLP (2018a) provides aerial index counts for Chinook, Chum, Coho, and Sockeye salmon adults in the SFK, NFK, and UTC mainstem segments and select tributaries from 2004 to 2008. Surveys on the SFK and NFK began at their confluence and extended upward to the intermittent reach or Frying Pan Lake on the SFK and upward to Big Wiggly Lake or river kilometer 56 on the NFK. Surveys on UTC ran from the mouth and extended upstream to Tributary 1.350 (just east of Kaktuli Mountain) or to the headwaters. Multiple counts were usually made for each stream and species in a given year.

Table 3-7 reports the minimum and maximum values for highest index spawner count in the SFK, NFK, and UTC mainstems, from 2004 through 2008 (SFK and NFK) or 2009 (UTC) (PLP 2018a: Chapter 15, Tables 15-14 through 15-17). Peak index counts capture only a portion of total spawning run abundance, because only a portion of the spawning population is present on the spawning grounds on any given day. Individual spawners are visible on their spawning grounds for days to weeks (e.g., Bue et al. 1998), but the spawning season can extend for weeks to months in the SFK, NFK, and UTC watersheds.

(PLP 2018a). The highest peak index counts for Coho and Sockeye salmon were in UTC, whereas the highest counts for Chinook and Chum salmon were in the SFK and NFK (Table 3-7). The overall highest count was for Sockeye Salmon in UTC in 2008, when approximately 50,317 fish were estimated (Table 3-7).

Table 3-7. Highest reported index spawner counts in the South Fork Kaktuli River, North Fork Kaktuli River, and Upper Talarik Creek, based on mainstem aerial surveys.

Watershed	Years Surveyed	Salmon Species	Number of Surveys Counted Per Year (Min-Max)	Highest Index Spawner Count (Year of Count) ^a	
				Minimum Value	Maximum Value
South Fork Kaktuli River	2004–2008	Chinook	3–9	327 (2006)	2,780 (2004)
		Chum ^b	4–11	189 (2007)	917 (2008)
		Coho	2–21	270 (2004)	1,955 (2008)
		Sockeye	3–14	1,730 (2004)	6,133 (2008)
North Fork Kaktuli River	2004–2008	Chinook	3–8	434 (2008)	2,889 (2005)
		Chum	1–9	350 (2005)	1,432 (2008)
		Coho	1–17	114 (2007)	1,704 (2008)
		Sockeye	2–11	563 (2004)	2,188 (2007)
Upper Talarik Creek	2004–2009	Chinook	2–9	80 (2009)	272 (2004)
		Chum ^b	1–8	3 (2005)	44 (2008)
		Coho	2–21	1,041 (2005)	7,542 (2009)
		Sockeye	2–20	10,557 (2007)	50,317 (2008)

Notes:

^a Values likely underestimate true spawner abundance (see Appendix B of this document for additional information).

^b Chum were not counted in the North Fork Kaktuli or Upper Talarik Creek in 2004.

Source: PLP 2018a: Chapter 15, Tables 15-14 through 15-17.

Aerial counts of adult salmon were also conducted in tributaries of the SFK, NFK, and UTC between 2004 and 2009 (Table 3-8). Adult Coho and Chum salmon were counted in SFK tributaries; adult Coho and Sockeye salmon were counted in NFK tributaries; and adult Coho, Chinook, Chum, and Sockeye salmon were counted in UTC tributaries. The highest number of adults reported in tributaries of each watershed were 50 Coho Salmon (SFK 1.190), 111 Sockeye Salmon (NFK 1.240), and 31,922 Sockeye Salmon (UTC 1.160) (Table 3-8).

Table 3-8. Highest reported number of adult salmon in tributaries of the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek, based on aerial surveys.

Watershed	Tributary	Years Surveyed	Total Number of Surveys (Min-Max Number of Surveys Per Year) ^a	Salmon Species ^b	Highest Reported Number in an Individual Survey
South Fork Koktuli River	SFK 1.130	2004-2008	26 (0-24)	Chum	6
				Coho	48
	SFK 1.190	2004-2008	42 (0-24)	Chum	28
				Coho	50
	SFK 1.240	2004-2008	26 (0-14)	Coho	5
North Fork Koktuli River	NFK 1.190 °	2004-2008	39 (0-21)	Coho	27
				Coho	12
	NFK 1.240 °	2004-2008	26 (1-17)	Sockeye	111
	NFK 1.260	2004-2008	11 (0-10)	Coho	4
	NFK 1.270	2004-2008	6 (0-5)	Coho	23
Upper Talarik Creek	UTC 1.160	2008-2009	42 (18-24)	Coho	1,079
				Sockeye	31,922
	UTC 1.190	2004-2009	53 (0-22)	Sockeye	49
	UTC 1.350 °	2004-2009	52 (1-25)	Chum	3
				Coho	571
				Sockeye	57
	UTC 1.390 °	2007-2009	(1-27)	Coho	29
				Sockeye	115
	UTC 1.410	2004-2009	34 (0-19)	Chinook	2
				Chum	21
				Coho	43
				Sockeye	30
	UTC 1.460	2004-2005	3 (1-2)	Coho	7

Notes:

^a In all but one case, the maximum number of surveys occurred in 2008.^b Only tributaries and salmon species with at least one survey count greater than one are listed.^c NFK 1.190 also includes NFK 1.190.10; NFK 1.240 also includes NFK 1.240P1, 1.240P1 Big Wiggly Lake, and 1.240.20.P1; UTC 1.350 also includes 1.350.20, 1.350.20P1, 1.350.20P2, and 1.350.20P3; UTC 1.390 also includes 1.390.20P2.

Source: PLP 2018a: Chapter 15, Appendix 15B2.

Mainstem and off-channel habitats of the SFK, NFK, and UTC also provide abundant habitat for juvenile salmonids. Table 3-9 presents maximum estimated densities and total numbers observed for juvenile Pacific salmon species in mainstem SFK, NFK, and UTC reaches (PLP 2018a: Chapter 15, USACE 2020a). Reported fish densities summarized over the 5-year period vary widely by stream and reach, which is typical for fishes in heterogeneous stream environments. The highest maximum estimated density for juvenile salmon was approximately 124 juvenile Coho Salmon in UTC Reach F (Table 3-9). Habitat-specific densities were much higher, however: for example, a density of approximately 1,600 Coho Salmon (of which roughly 90 percent were juveniles) per 100 m² of pool habitat was estimated in UTC Reach D (PLP 2011: Figure 15.1-82).

Table 3-9. Maximum estimated densities and total observed number of juvenile Pacific salmon in mainstem habitats of the South Fork Kaktuli River, North Fork Kaktuli River, and Upper Talarik Creek.

Watershed/Reach (River Kilometers)	Maximum Estimated Density (# per 100 m ²) ^a			Total Number Observed at Mainstem Index Sites ^b		
	Chinook	Coho	Sockeye	Chinook	Coho	Sockeye
South Fork Kaktuli River						
SFK-A (0.0–24.9)	24.86	37.40	1.77	1,246	762	29
SFK-B (24.9–34.3)	0.21	20.21	0.57	4	292	8
SFK-C (34.3–51.7)	0.12	19.77	0.35	4	101	-
SFK-D (51.7–54.7)	1.39	2.52	0.00	-	-	-
SFK-E (54.7–64.2)	0.00	1.18	0.00	-	1	-
North Fork Kaktuli River						
NFK-A (0.0–13.7)	18.84	17.67	0.15	802	415	7
NFK-B (13.7–21.1)	30.68	34.52	1.18	95	190	-
NFK-C (21.1–36.6)	8.24	28.07	1.89	213	624	42
NFK-D (36.6–48.4)	0.38	2.73	0.12	-	23	1
NFK-E (48.4–52.5)	0.00	0.00	0.00	-	-	-
Upper Talarik Creek						
UTC-A (0.0–5.9)	0.38	1.25	0.00	10	33	-
UTC-B (5.9–16.8)	17.62	46.24	0.14	61	931	-
UTC-C (16.8–24.8)	11.31	67.24	2.28	101	422	1
UTC-D (24.8–36.3)	4.64	48.99	0.29	6	868	-
UTC-E (36.3–45.1)	4.77	115.42	4.12	5	1,240	5
UTC-F (45.1–59.1)	1.53	123.78	0.67	-	992	1
UTC-G (59.1–62.4)	0.00	21.53	0.00	-	2	-

Notes:

^a Maximum estimated juvenile density across values reported for 2004–2007, 2008, and 2009.^b Total number of juveniles observed across index sites within given reach in 2009, surveyed by beach seine and snorkel methods. South Fork Kaktuli River sites were sampled 7/24 to 8/28; North Fork Kaktuli River sites were sampled 7/25 to 8/21; Upper Talarik Creek sites were sampled 7/26 to 8/28. Dash (-) indicates that no counts for the given species were reported within that reach.

Source: USACE 2020a: Table 3.24-9, PLP 2018a: Chapter 15, Table 15-11.

Abundant and diverse off-channel habitats are also found in the SFK, NFK, and UTC watersheds (Section 3.2.2). Aerial imagery shows that roughly 70 percent of the mainstem SFK and UTC and roughly 90 percent of the mainstem NFK are bordered by some form of off-channel habitat (USACE 2020a: Section 3.24), most commonly beaver complexes (Section 3.2.2) (USACE 2020a: Section 3.24). Off-channel habitats provide important rearing habitat for many fish species but may be especially important as rearing and overwintering habitats for juvenile salmonids (Huntsman and Falke 2019, USACE 2020a: Section 3.24). Table 3-10 highlights the diversity of both off-channel habitats and the fish species that rely on them in the SFK, NFK, and UTC watersheds. Relative abundance in these habitats was highest for Coho Salmon, with an estimate of more than 1,300 fish per 100 meters.

Table 3-10. Relative abundance of salmonids in off-channel habitats of the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek.

Watershed	Off Channel Habitats		Number of Fish Per 100 Meters					
	Type	No. of Sites	Chinook Salmon	Coho Salmon	Sockeye Salmon	Arctic Grayling	Dolly Varden	Rainbow Trout
South Fork Koktuli River ^a	Alcove	-	-	-	-	-	-	-
	Beaver pond	36	2.94	30.38	10.84	7.37	4.29	0
	Beaver pond outlet channel	-	-	-	-	-	-	-
	Isolated pool	2	0	8.22	2.35	0	0	0
	Percolation channel	2	0	11.43	0	0	0	0
	Side channel	3	10.34	66.41	5.17	0.52	0	0.52
North Fork Koktuli River ^b	Alcove	1	2.06	1,334.02	24.74	0	12.37	0
	Beaver pond	9	0.18	78.19	0.53	0	1.07	0
	Beaver pond outlet channel	1	0	0	0	0	0	0
	Isolated pool	2	0	0	0	0	0	0
	Percolation channel	16	2.49	51.60	0.62	0	8.70	0
	Side channel	8	0	568.13	0	0	69.21	0
Upper Talarik Creek ^c	Alcove	1	0	87.10	0	0	0	0
	Beaver pond	24	1.38	317.41	0.42	0.26	1.38	0.42
	Beaver pond outlet channel	3	0	42.38	0	0	1.32	1.32
	Isolated pool	4	0	15.09	0	0	0	0
	Percolation channel	10	0.63	144.38	3.92	12.54	0.16	0.78
	Side channel	3	0.75	270.33	1.51	0	0.75	0

Notes:

- ^a Off-channel sites in the South Fork Koktuli River were sampled in September 2005, June and August 2006, and July 2007; it is not clear if or how data from sampling dates were combined to arrive at table values.
- ^b Off-channel sites in the North Fork Koktuli River were sampled between late July to mid-August 2008; it is not clear if or how data from sampling dates were combined to arrive at table values.
- ^c Off-channel sites in Upper Talarik Creek were sampled in July and October 2007; it is not clear if or how data from these sampling dates were combined to arrive at table values.

Source: PLP 2011: Chapter 15, Appendix 15.1D, Table 6.

As Table 3-3 illustrates, the SFK, NFK, and UTC watersheds are home to several fish species in addition to Pacific salmon. Maximum estimated densities for a subset of these other fishes in the SFK, NFK, and UTC mainstem reaches are shown in Table 3-11. Estimated densities were highest for Arctic Grayling, particularly in upstream reaches of all three watersheds.

Table 3-11. Maximum estimated densities of resident fishes in mainstem habitats of the South Fork Kaktuli River, North Fork Kaktuli River, and Upper Talarik Creek.

Watershed/Reach (River Kilometers)	Maximum Estimated Density (# per 100 m ²) ^a					
	Rainbow Trout	Dolly Varden	Arctic Grayling	Northern Pike	Sculpin spp.	Stickleback spp.
South Fork Kaktuli River						
SFK-A (0.0–24.9)	0.03	3.44	0.67	0.00	2.52	0.00
SFK-B (24.9–34.3)	0.29	0.64	2.47	0.00	1.29	0.00
SFK-C (34.3–51.7)	0.00	0.82	35.31	0.47	4.94	0.21
SFK-D (51.7–54.7)	0.00	5.55	45.02	1.26	19.78	0.00
SFK-E (54.7–64.2)	0.00	0.00	15.90	2.36	9.29	0.15
North Fork Kaktuli River						
NFK-A (0.0–13.7)	0.23	0.74	2.44	0.00	1.52	0.00
NFK-B (13.7–21.1)	0.00	0.24	0.21	0.00	2.01	0.00
NFK-C (21.1–36.6)	0.00	1.76	6.68	0.00	1.76	0.00
NFK-D (36.6–48.4) ^b	0.00	1.05	6.01	0.10	6.77	0.19
NFK-E (48.4–52.5) ^b	0.00	0.00	0.00	0.00	10.00	0.00
Upper Talarik Creek						
UTC-A (0.0–5.9) ^b	0.11	0.00	0.04	0.00	0.66	14.55
UTC-B (5.9–16.8) ^b	10.64	0.20	0.61	0.00	1.96	0.00
UTC-C (16.8–24.8)	11.03	0.47	32.10	0.00	13.31	0.54
UTC-D (24.8–36.3)	0.45	1.22	1.19	0.00	3.70	0.44
UTC-E (36.3–45.1)	0.32	0.44	0.70	0.00	7.53	0.04
UTC-F (45.1–59.1)	0.87	3.35	0.43	0.00	28.65	0.17
UTC-G (59.1–62.4)	0.00	7.46	0.00	0.00	16.58	0.00

Notes:

^a Maximum estimated adult and juvenile density across values reported for 2004–2007, 2008, and 2009.^b Reach was not sampled from 2004–2007.

Source: USACE 2020a: Table 3.24-9.

3.3.3 Habitat Complexity, Biocomplexity, and the Portfolio Effect

The world-class salmon fisheries in Bristol Bay result from numerous, interrelated factors. Closely tied to the Bristol Bay region's physical habitat complexity (Section 3.2) is its biocomplexity, which greatly increases the region's ecological productivity and stability. This biocomplexity operates at multiple scales and across multiple species, but it is especially evident in the watershed's Pacific salmon populations (Shedd et al. 2016). As a result, the loss of even a small, discrete population within the Bristol Bay watershed's overall salmon populations may have more significant effects than expected, due to associated decreases in biocomplexity.

3.3.3.1 The Relationship between Habitat Complexity and Biocomplexity

The five Pacific salmon species found in the Bristol Bay watershed vary in life-history characteristics (Table 3-4). Even within a single species, life histories can vary significantly. For example, Sockeye Salmon may spend anywhere from 0 to 3 years rearing in freshwater habitats, then 2 to 3 years feeding at sea, before returning to the Bristol Bay watershed anytime within a 4-month window (Table 3-4). Coho Salmon similarly may spend anywhere from 1 to 3 years rearing in freshwater habitats

(Table 3-4). This staggered and overlapping age structure reduces variation in recruitment because it reduces the probability that all individuals in a cohort of siblings will encounter unfavorable environmental conditions over the course of their life cycles.

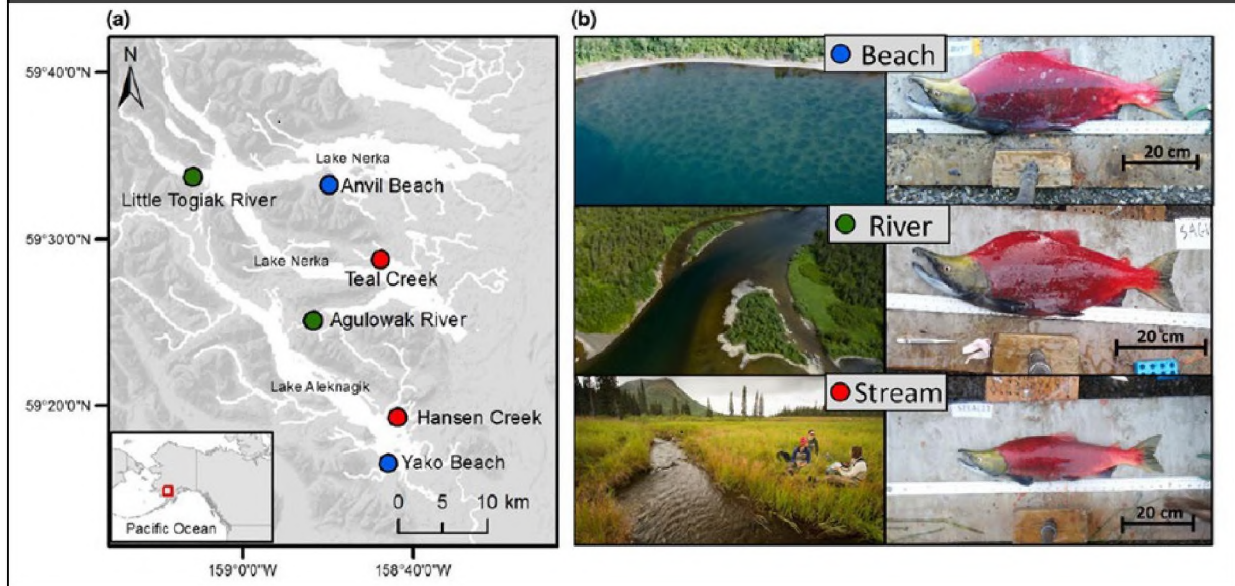
Pacific salmon exhibit homing behavior, meaning that they return to their natal streams to spawn. This homing behavior reduces gene flow between breeding groups and allows natural selection and genetic drift to produce discrete populations within each species that are adapted to their own specific spawning and rearing habitats and that are distinguishable using various genetic tools (Hilborn et al. 2003, Ramstad et al. 2010, Schindler et al. 2010, Larson et al. 2019). As research tools have improved, it is increasingly clear that population differentiation can occur at very fine spatial scales (Quinn et al. 2012), enabled by the remarkable homing abilities of Pacific salmon species (Quinn et al. 2006) and driven by differences in environmental characteristics such as thermal regime and water chemistry (Ruff et al. 2011, Keefer and Caudill 2014).

Both geography and ecology influence this genetic divergence within salmon species (Gomez-Uchida et al. 2011). Spawning populations return at different times and to different locations, creating and maintaining a degree of reproductive isolation due to reduced genetic exchange and allowing development of genetically distinct populations (Varnavskaya et al. 1994, Hilborn et al. 2003, McGlaufflin et al. 2011). Within discrete spawning areas, natural selection may favor traits differently based on the unique environmental characteristics of spawning or rearing areas. For example, phenotypic variation in Sockeye Salmon body size and shape in the Bristol Bay region has been related to gravel size and spawning habitat (Quinn et al. 1995, Quinn et al. 2001, Larson et al. 2017, Schindler et al. 2018), illustrating the apparent adaptive significance of this variation.

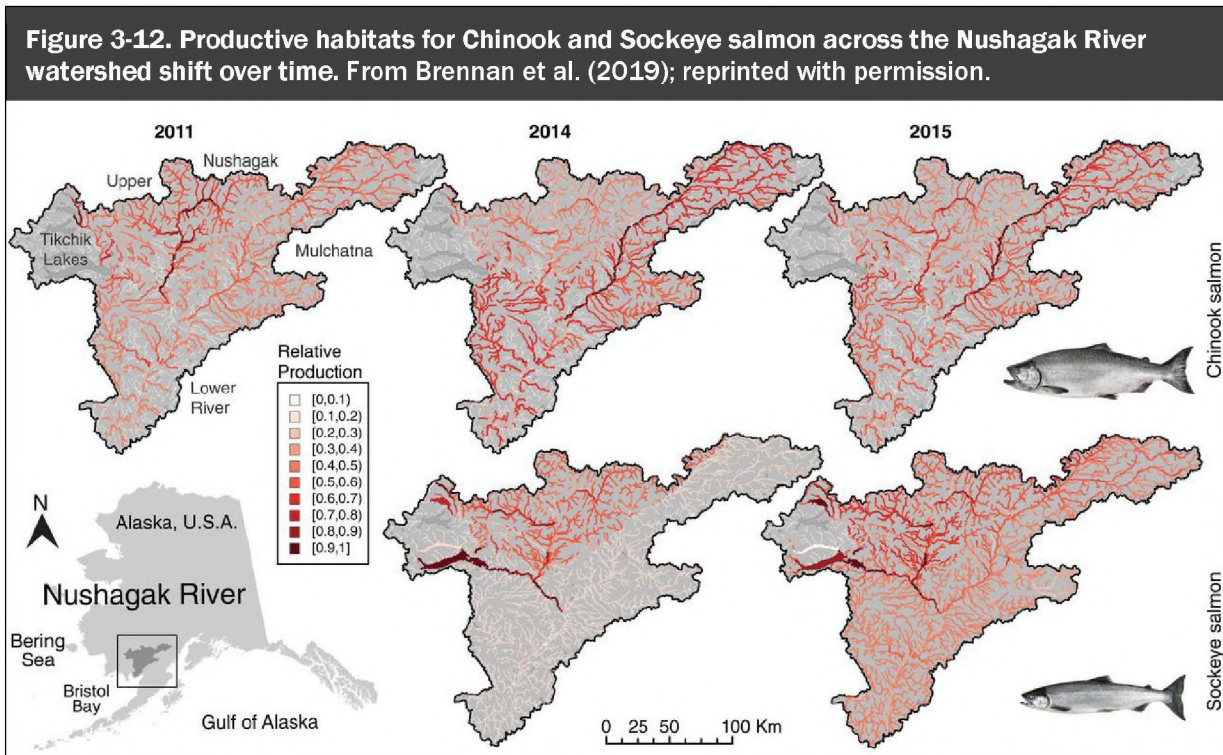
These life history characteristics allow Pacific salmon species to fully exploit the range of habitats available throughout the Bristol Bay watershed, where many populations of each of these species are arrayed across a diverse landscape. Hydrologically diverse riverine and wetland landscapes across the region provide a variety of large river, small stream, floodplain, pond, and lake habitats for salmon spawning and rearing. Environmental conditions can differ among habitats in close proximity, and variations in temperature and streamflow associated with seasonality and groundwater-surface water interactions create a habitat mosaic that supports a range of spawning times across the watersheds (Lisi et al. 2013, Schindler et al. 2018).

Bristol Bay is home to the largest Sockeye Salmon fishery in the world (Section 3.3.5). Sockeye Salmon from Bristol Bay produce relatively consistent returns due to the high degree of population diversity found within both the species and the region (Hilborn et al. 2003, Wood et al. 2008, Schindler et al. 2010, Schindler et al. 2015, Moore et al. 2021). A major component of this population diversity is associated with the diversity of habitats used for spawning, which has resulted in the formation of distinct spawning ecotypes (Figure 3-11) (Quinn et al. 1995, Lin et al. 2008a, Dann et al. 2012, Larson et al. 2017, Schindler et al. 2018).

Figure 3-11. Bristol Bay salmon genetic lines of divergence linked to ecotypes. Genotypic and phenotypic diversity are linked in Sockeye Salmon from the Wood River system in Bristol Bay, providing an example of phenotypic variation due to selective adaptive pressures from the diversity of habitats (beaches, rivers, and streams) across the landscape. From Larson et al. (2017); reprinted with permission.

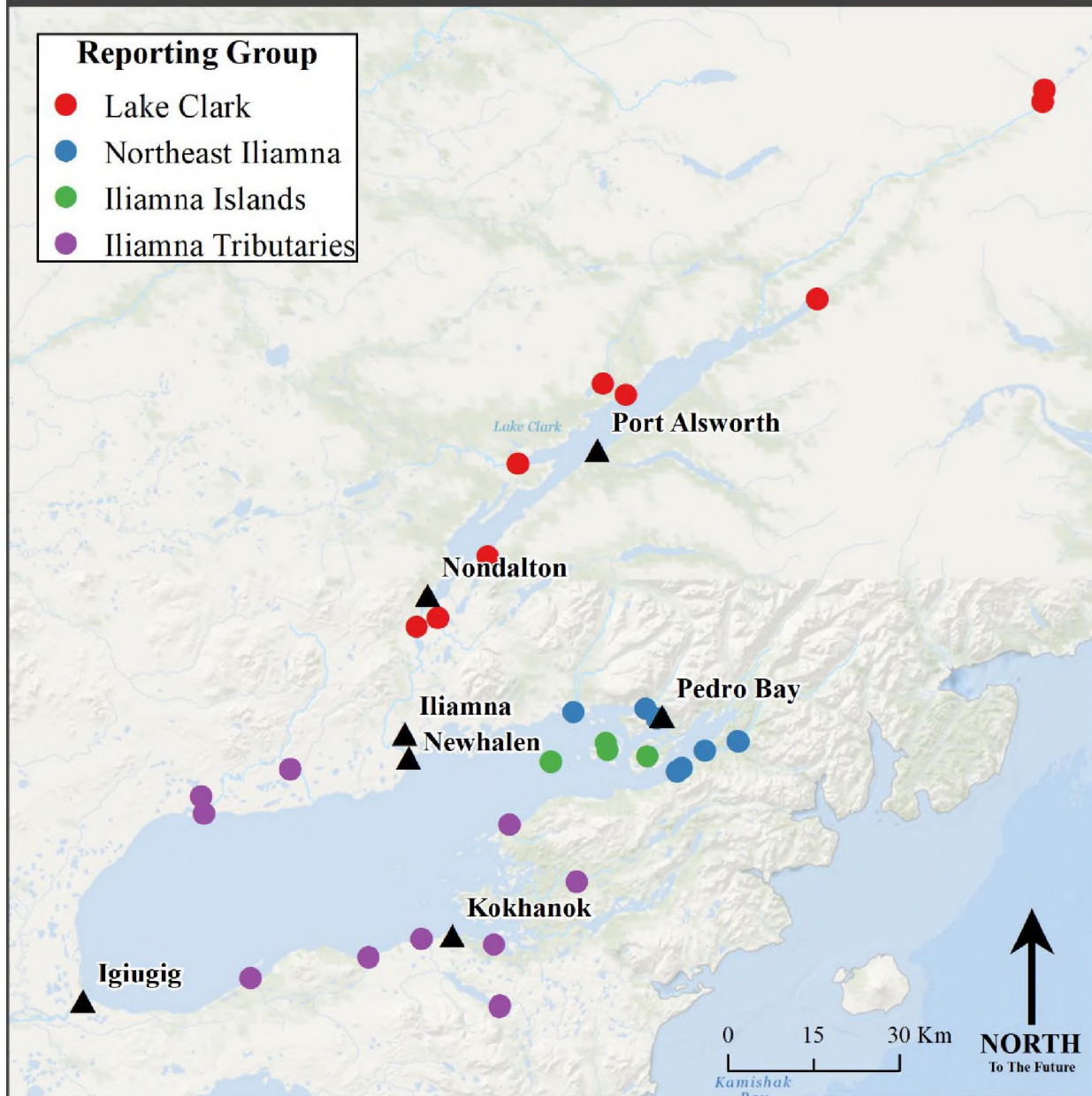


For both Chinook and Sockeye salmon, biocomplexity—operating across a continuum of integrated, nested spatial and temporal scales—stabilizes salmon production and fisheries in the Nushagak River watershed (Brennan et al. 2019). Productivity of Sockeye and Chinook salmon shifts within the Nushagak River watershed from year to year (Figure 3-12). Because the productivity of individual habitats and sub-watersheds in the Nushagak River watershed varies with environmental conditions, maintaining habitat diversity across the landscape is critical for maintaining the sustainability and productivity of the watershed's salmon populations. The phenotypic, genotypic, and behavioral diversity of these salmon populations depends on the diversity of aquatic habitats in space and time (Davis et al. 2017, Schindler et al. 2018, Brennan et al. 2019).



Although this genetic differentiation and associated phenotypic differences tend to increase with distance between the populations, even populations in relatively close proximity can exhibit high degrees of differentiation (May et al. 2020). As a result, these discrete populations can occur at localized spatial scales. For example, Sockeye Salmon that use spring-fed ponds and streams approximately 0.6 mile (1 km) apart exhibit differences in spawn timing, productivity, and other traits that are consistent with discrete populations (Quinn et al. 2012). Multiple beach-spawning populations of Sockeye Salmon are found in Iliamna Lake (Figures 3-11 and 3-13) (Stewart et al. 2003, Larson et al. 2017). Genetically distinct river-type and lake-type populations can co-occur within watersheds (Dann et al. 2013, Shedd et al. 2016, Larson et al. 2017), and inlet and outlet spawners with distinct migration patterns can occur within the same lake (Burger et al. 1997). Iliamna Lake supports genetically unique populations within tributary, island, and lake shoreline ecotones, with UTC identified as the location of one of the 22 populations (Figure 3-13). Genetic diversity of Sockeye Salmon in Bristol Bay has been found to be distributed hierarchically between ecotypes, among drainages within ecotypes, and among populations within drainages (Figure 3-11) (Dann et al. 2013, Larson et al. 2017, Schindler et al. 2018, Larson et al. 2019).

Figure 3-13. Kvichak River Sockeye Salmon populations. 22 populations of Sockeye Salmon (color-coded by reporting group) have been identified in the Kvichak River. From Dann et al. (2018); reprinted with permission.



Sockeye Salmon that spawn in small streams tend to be smaller than beach or river spawners, as shallow stream depths and size-selective predation by bears favor survival of smaller spawning adults (Figure 3-11) (Quinn et al. 2001, Larson et al. 2017). These different spawning environments also vary in other characteristics, such as temperature, gravel size, and spawning density, resulting in differences in egg size (Quinn et al. 1995, Hendry et al. 2000), timing of spawning (Schindler et al. 2010) and pathogen susceptibility (hypothesized in Larson et al. 2014). Local adaptation to these diverse habitats is key to creating and preserving salmon genetic diversity.

The river-type form of Sockeye Salmon, with juveniles that rear in rivers and tributaries for one or more years before migrating to the ocean, is relatively rare in Bristol Bay; the lake-type form, with juveniles that rear in lakes for one or more years before migrating, is more common (Wood et al. 2008). However, river-type Sockeye Salmon are found in the Nushagak River watershed, including in the Koktuli River (Dann et al. 2012). River-type Sockeye Salmon represent an important form of genetic diversity, as these populations typically exhibit greater diversity within and less diversity among populations than the more abundant lake-type sockeye salmon (Larson et al. 2019). It has been hypothesized that river-type Sockeye Salmon have a greater tendency than lake-type Sockeye Salmon to stray from natal areas and, thus, may be the colonizers of the species (Wood 1995, Wood et al. 2008). In this manner, life history and genetic diversity can help “seed” new freshwater habitats that become available (e.g., as glaciers recede due to climate change [Pitman et al. 2020]).

3.3.3.2 The Portfolio Effect

The life-history complexity of Bristol Bay’s Pacific salmon species is superimposed on localized adaptations, resulting in a high degree of biocomplexity organized into discrete, locally distinct fish populations. For example, the Bristol Bay watershed includes a complex of different Sockeye Salmon populations—that is, a combination of hundreds of genetically distinct, wild populations, each adapted to specific, localized environmental conditions (Hilborn et al. 2003, Schindler et al. 2010, Schindler et al. 2018). As genetic tools and techniques develop, the science continues to advance our understanding of the prevalence and importance of individual populations.

Management of Alaska’s salmon fisheries is geared toward protection of these wild salmon populations, or stocks (5 AAC 39.222, 5 AAC 39.220, 5 AAC 39.223, 5 AAC 39.200). The ADF&G Genetic Policy provides the fundamental document for guiding decisions made to protect the genetic integrity of significant and unique wild stocks (Evenson et al. 2018), and the mission of the ADF&G Gene Conservation Laboratory includes the protection of these genetic resources. The foundational premise behind the Genetic Policy guidelines is that salmonid populations have adapted to their native habitats over long periods of time and, thus, have maximized their fitness. These adaptations among populations provide increased resilience to variation in environmental conditions (Figge 2004, Schindler et al. 2010); disruption of these adaptations reduces the long-term fitness of populations.

This complex structure of genetically distinct populations can be likened to a financial portfolio in which assets are divided among diverse investments to increase financial stability. Essentially, it creates a biological portfolio effect (Lindley et al. 2009, Schindler et al. 2010, Schindler et al. 2015): under any

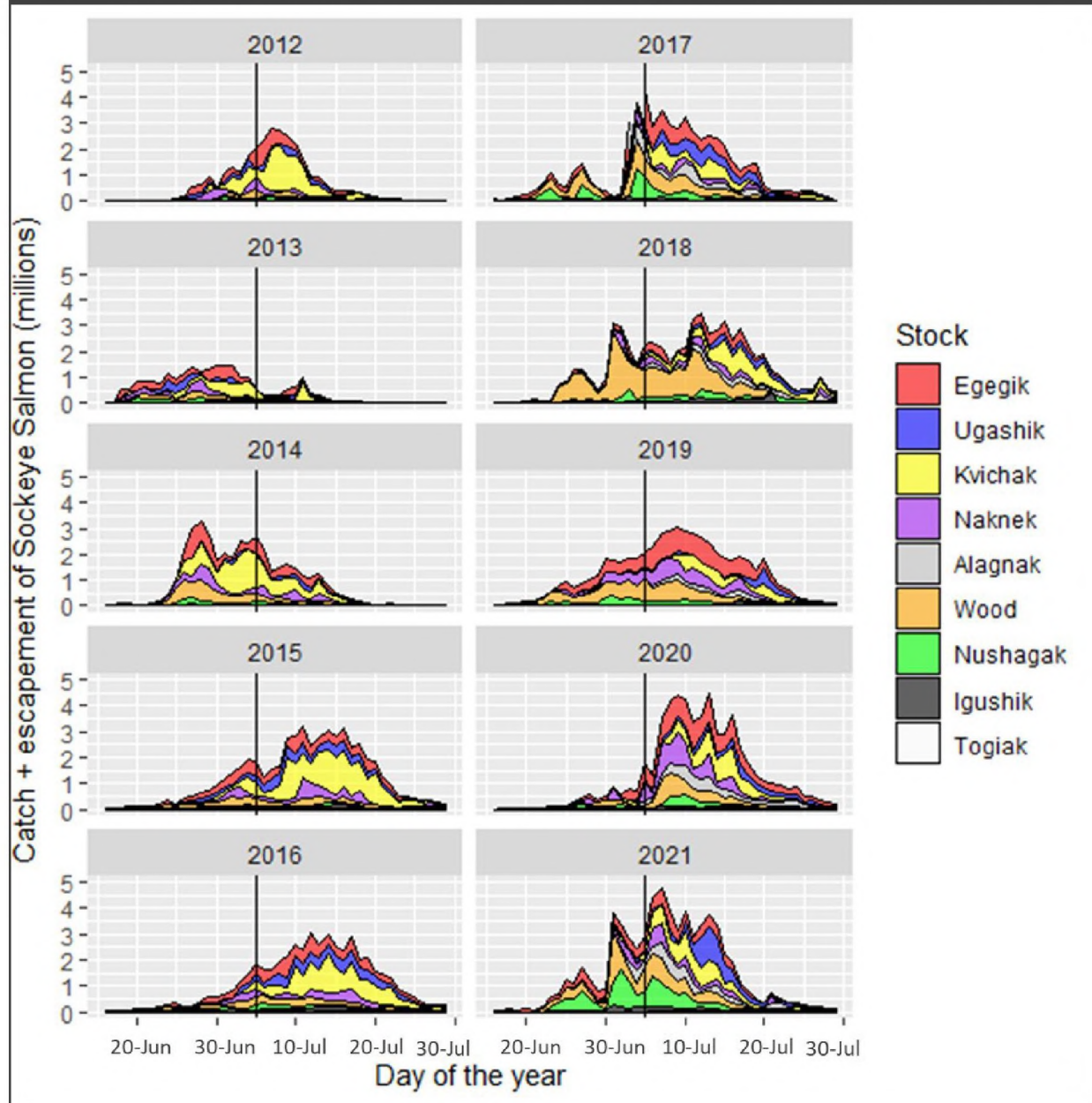
given set of conditions, some assets (e.g., discrete Sockeye Salmon populations) will perform well while others perform less well, but maintenance of the diversified portfolio stabilizes returns over time because fluctuations of these discrete populations are asynchronous.

The portfolio concept is based on three key principles: (1) diversity provides stabilization; (2) habitat diversity creates genetic and phenotypic diversity in space and time; and (3) genetic and phenotypic diversity dampen ecological risk through asynchrony of population dynamics (i.e., spawning, rearing, migration) across the landscape (Schindler et al. 2010). Across the entire watershed, overall salmon productivity is stabilized as the relative contributions of Sockeye Salmon that differ in genetic structure and life-history characteristics and that inhabit different regions of the Bristol Bay watershed change over time, in response to changing environmental conditions (Hilborn et al. 2003).

Asynchrony in the productivity of different populations within the complex has been demonstrated at both local and regional scales—that is, across individual tributaries and across the Bristol Bay watershed's major river systems (Rogers and Schindler 2008, Schindler et al. 2010, Griffiths et al. 2014, Raborn and Link 2022). This asynchrony among populations is an important characteristic of stable ecosystems (Rogers and Schindler 2008, Quinn et al. 2012). At the local scale, for example, salmon populations that spawn in small streams may be negatively affected by low-streamflow conditions, whereas populations that spawn in lakes may not be affected (Hilborn et al. 2003). At the regional scale, the relative productivity of Bristol Bay's major rivers has changed over time during different climatic regimes (Hilborn et al. 2003, Raborn and Link 2022). For example, small Sockeye Salmon runs in the Egegik River were offset by large runs in the Kvichak River prior to 1977, whereas declining runs in the Kvichak River were offset by large runs in the Egegik River in the 2000s (EPA 2014: Appendix A, Figure 9). Figure 3-14 illustrates how the proportion of Sockeye Salmon catch from each of Bristol Bay's major rivers varies both within and across years.

Asynchrony of population dynamics across a diverse set of habitats has enabled the Bristol Bay salmon fishery to be less variable and more reliable and sustainable than would otherwise be the case (Davis and Schindler 2021). The high level of system-wide biocomplexity inherent in the overall population complex structure reduces year-to-year variability in salmon run sizes. Without the portfolio effect, annual variability in the size of Bristol Bay's Sockeye Salmon runs would be expected to more than double, and fishery closures would be expected to become more frequent due to a weakening of the portfolio (Schindler et al. 2010, Griffiths et al. 2014). Simulations have shown that loss of headwater salmon populations can reverberate throughout the river network, resulting in reduced catch stability and increased fishery variability at the most downstream locations (Moore 2015). In other watersheds with previously robust salmon fisheries, such as the Sacramento River's Chinook Salmon fishery, losses of biocomplexity have contributed to overall salmon population declines (Lindley et al. 2009). Loss of accessible floodplain and headwater habitats also can be a significant driver of these declines, as illustrated in Canada's Lower Fraser River (Finn et al. 2021).

Figure 3-14. Seasonal catch plus escapement of Sockeye Salmon for each genetically distinct stock in Bristol Bay, Alaska, 2012–2021. Escapement refers to the number of adult salmon that “escape” harvest and return to freshwaters to spawn. Black vertical lines denote July 4, to facilitate run timing comparison across years. From Raborn and Link (2022); reprinted with permission.

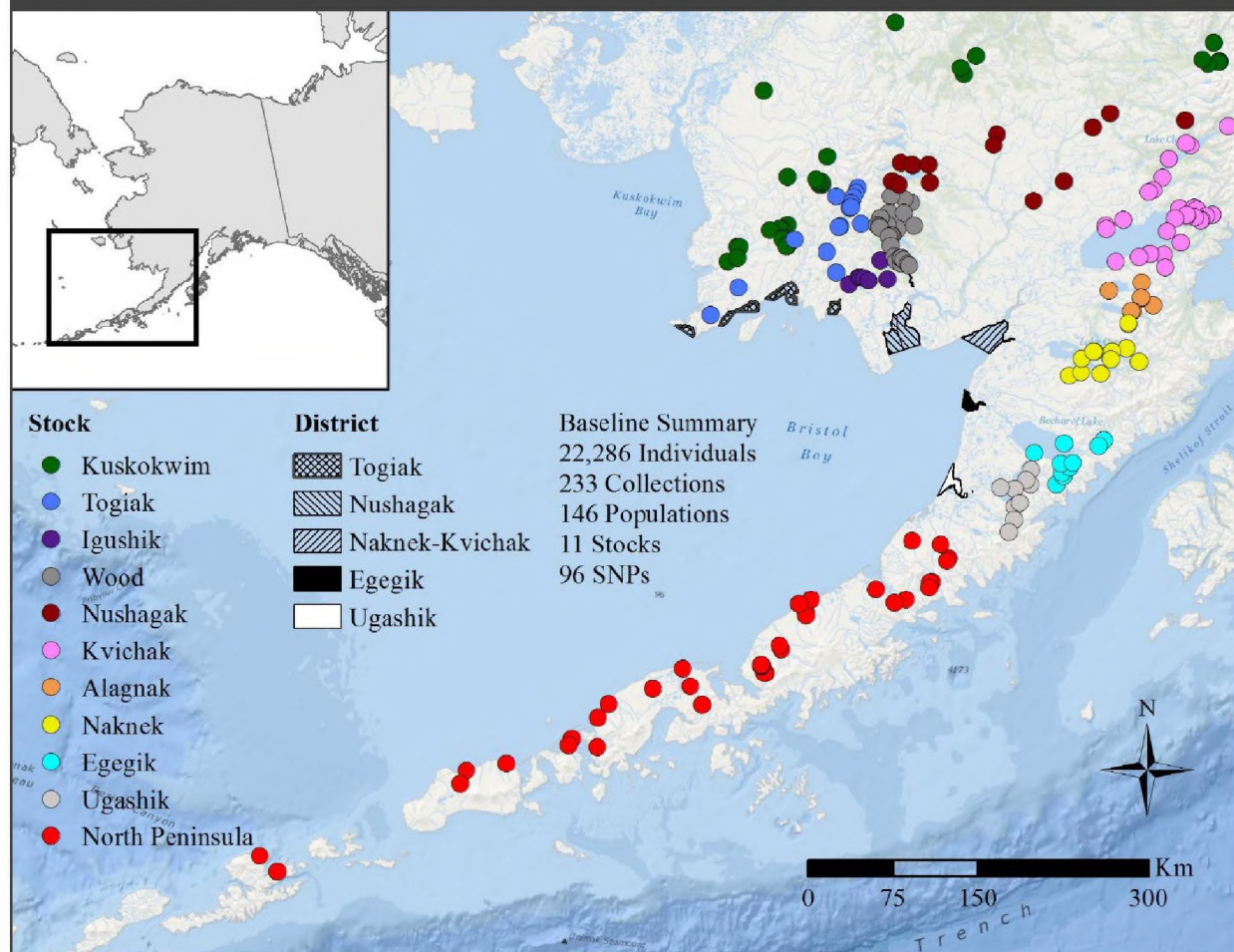


ADF&G has identified 11 genetic reporting groups (stocks), corresponding to nine major watersheds of Bristol Bay⁴⁸ and the two flanking regions (North Peninsula to the south and Kuskokwim to the north) (Figure 3-15). In Bristol Bay, a “stock” has been defined as a composite of all populations of a given species within each of those 11 watersheds (Dann et al. 2009). Each river stock contains tens to hundreds of wild, locally adapted populations distributed among tributaries and lake habitats. In Bristol Bay, the ADF&G Sockeye Salmon genetic baseline, which is assembled by sampling spawning populations contributing to the commercial fishery (Section 3.3.5), has recently increased from 96 to 146 distinct populations that range from the Kuskokwim River (to the north) to the Aleutian Islands (to the south) (Dann et al. 2013). Even this higher value likely underestimates the actual number of distinct breeding groups. Prior to the development of genetic tools and the current genetic baseline, Demory et al. (1964) catalogued Sockeye Salmon spawning sites of the Kvichak River system, including UTC. This catalog represents historical recognition of nearly 100 distinct stream and beach Sockeye Salmon spawning groups in the Kvichak River system alone. Given technological advances in genetic methods and the fact that this region has remained largely undeveloped and undisturbed since this initial estimate, it seems likely that additional genetic diversity will continue to be identified as further sampling of spawning groups and analysis of genetic structuring occur.

The genetic population structure of Bristol Bay Sockeye Salmon indicates that upper Mulchatna River fish are distinct from lower Mulchatna River fish, and that both of these populations are genetically distinct from the upper Nushagak River fish. Sockeye Salmon spawning in the Kaktuli River are part of the Lower Mulchatna River and have recently been determined to be genetically distinct (Dann et al. 2012, Shedd et al. 2016). This incredible local diversity of Sockeye Salmon—which translates to the robustness of the region’s Sockeye Salmon portfolio—reflects the species’ ability to exploit a wide range of habitat conditions, the reproductive isolation of populations created by precise homing to natal spawning sites and, thus, the species’ capacity for microevolution.

⁴⁸ Figure ES-1 shows six major watersheds draining to Bristol Bay, whereas Dann et al. (2009) refer to nine major watersheds. This difference results from consideration of the Igushik and Wood River watersheds as distinct from the Nushagak River watershed and the Alagnak River watershed as distinct from the Kvichak River watershed in Dann et al. (2009).

Figure 3-15. Reporting group affiliation for 146 Sockeye Salmon populations in Bristol Bay. These populations are used to estimate stock composition of catch samples from the Port Moller Test Fishery and district harvests. SNP = single nucleotide polymorphism, a common type of genetic marker. From Dann et al. 2013; reprinted with permission.



The close management of mixed-stock fisheries allows for the capitalization of genotypic and phenotypic diversity of Bristol Bay Sockeye Salmon while spreading the risk to any one stock across the stock portfolio (Veale and Russello 2017). The buffering effect of the salmon portfolio is reflected in the 2022 Bristol Bay Sockeye Salmon Forecast (ADF&G 2021a), which reports that individual river forecasts have greater uncertainty compared to the Bristol Bay-wide forecast. ADF&G (2021a) notes that since 2001, the forecast has, on average, underestimated returns to the Alagnak (-33 percent), Togiak (-14 percent), Kvichak (-21 percent), Wood (-20 percent), Nushagak (-25 percent), Ugashik (-5 percent), and Naknek (-15 percent) Rivers, and overestimated returns to the Igushik (11 percent) and Egegik Rivers (13 percent). Over-forecasting returns to some rivers while under-forecasting returns to other rivers means that the overall Bristol Bay forecast is often more accurate than the forecast to any individual river. This illustrates the power of a diverse stock portfolio to provide sustained resiliency for Bristol Bay's Sockeye Salmon fishery, by buffering risk to any one stock temporally and spatially across multiple

stocks: certain rivers may have lower than expected returns in a given year due to environmental conditions and other factors, but these losses can be offset by higher than expected returns in other rivers (Figure 3-14).

Baseline genetic research suggests that other Bristol Bay fisheries, in addition to Sockeye Salmon, may also be stabilized by the portfolio effect; in fact, the basic biology of these species makes such stabilization virtually inevitable. However, other Pacific salmon species have been less intensively studied in general, and their genetic baselines are not currently as advanced as they are for Sockeye Salmon. Coho Salmon in western Alaska tend to occur in smaller, more isolated populations (Olsen et al. 2003). Thus, Coho Salmon may have higher rates of genetic differentiation than nearby populations of other salmon species (e.g., Chum Salmon) in this region, and the loss of Coho Salmon populations may be more likely to translate to loss of significant amounts of overall genetic variability (Olsen et al. 2003, Schindler et al. 2018).

Chinook Salmon populations also tend to be relatively small (Healey 1991) and exhibit diverse life history traits (e.g., variations in size and age at migration, duration of freshwater and estuarine residency, time of ocean entry) (Lindley et al. 2009). Chinook populations in the Togiak River differ in spawning habitats (mainstem versus tributary) and migration timing, which translates to a clear stock structure (Sethi and Tanner 2014, Clark et al. 2015). The Chinook Salmon population in the Nushagak River watershed (i.e., the Nushagak watershed genetic reporting group) is represented by several spawning aggregations: the Koktuli River near the confluence of the SFK and NFK, the Chilikadrotna River, the Mulchatna River, the Stuyahok River, Klutuspak Creek and the Iowithla River. Based on variations in allele frequencies, these six spawning aggregations are considered six genetically differentiated populations that cannot be pooled into a single baseline population (Howard et al. 2019). The Koktuli River aggregation is a large component of the overall Nushagak watershed genetic reporting group (Templin et al. 2011). The current Chinook Salmon baseline update includes tissue samples from adults collected on spawning grounds in the lower Koktuli River mainstem and the SFK. Spawning populations of Chinook Salmon are also found in portions of the NFK and the UTC, but these populations are not currently well represented in the genetic baseline for Chinook Salmon.

Pacific salmon are not the only fish species that display genetic differentiation in this region. Radio telemetry, tagging, phenotypic variation, and genetic studies also indicate that multiple Rainbow Trout populations are found in the Bristol Bay watershed (Burger and Gwartney 1986, Minard et al. 1992, Krueger et al. 1999, Meka et al. 2003, Dye and Borden 2018, Arostegui and Quinn 2019b, Arostegui et al. 2019).

The potential for fine-scale population structuring of salmon fisheries, particularly in terms of Sockeye and Coho salmon, exists throughout the entire Bristol Bay watershed. Finer-scale habitats can sustain unique, genetically distinct populations, each of which helps to maintain the integrity of overall salmon stocks across the Bristol Bay watershed and contributes to the overall resilience of these stocks to perturbation. For example, Sockeye Salmon populations in proximity to each other show phenotypic differences related to differences in spawning habitats (Lin et al. 2008b, Ramstad et al. 2010), and

Sockeye Salmon that use spring-fed ponds and streams as close as approximately 0.6 mile (1 km) apart exhibit differences in traits (e.g., spawn timing and productivity) that suggest they may comprise discrete populations (Quinn et al. 2012). Genetic population structure also occurs at a fine geographic scale for Coho Salmon, with many populations found in small first- and second-order headwater streams (Olsen et al. 2003). The ability of Bristol Bay to sustain diverse salmon populations therefore depends on sustaining the viability of the vast network of unique habitats at small spatial scales across the landscape. This suggests that even the loss of a small population within the Bristol Bay watershed's overall salmon populations may have more significant effects than expected, due to the associated loss of genetic and phenotypic diversity of a discrete population (Schindler et al. 2010, Moore et al. 2014, Waples and Lindley 2018).

In summary, a substantial body of research supports the conclusion that a diversity of habitats is necessary for maintaining locally adapted populations that create a stock portfolio of individual species. The multiple, genetically distinct populations of Sockeye Salmon that have been documented in the SFK, NFK, and UTC watersheds contribute to the region's wild salmon portfolio. It is clear from the evolving understanding of the stabilizing effects of the salmon portfolio that the conservation of habitat diversity and connectivity, which leads to locally adapted population diversity across the landscape, is critical to achieve and maintain the sustainability of Bristol Bay's salmon populations.

3.3.4 Salmon and Marine-Derived Nutrients

Salmon play a crucial role in maintaining and supporting the overall productivity of the Bristol Bay watershed. Salmon are a cornerstone species in the Bristol Bay region in that they comprise a significant portion of the resource base upon which both aquatic and terrestrial ecosystems in the region depend (Willson et al. 1998). Approximately 95 to 99 percent of the carbon, nitrogen, and phosphorus in an adult salmon's body is derived from the marine environment during their ocean feeding period (Larkin and Slaney 1997, Schindler et al. 2005). Adult salmon returning to their natal freshwater habitats to spawn import these marine-derived nutrients (MDN) back into these freshwater habitats, spatially and temporally across the watershed (Cederholm et al. 1999, Gende et al. 2002). MDN from salmon account for a significant portion of nutrient budgets in the Bristol Bay watershed (Kline et al. 1993). For example, Sockeye Salmon were estimated to import approximately 14 tons (12.7 metric tons) of phosphorus and 11 tons (10.1 metric tons) of nitrogen into the Wood River system, and 55 tons (50.2 metric tons) of phosphorus and 438 tons (397 metric tons) of nitrogen into the Kvichak River system, annually (Moore and Schindler 2004). These nutrients provide the foundation for aquatic and terrestrial foodwebs via two main pathways: direct consumption of salmon in any of its forms (spawning adults, eggs, carcasses, and/or juveniles) and nutrient recycling (Gende et al. 2002).

Given that aquatic systems in the Bristol Bay watershed tend to be nutrient-poor, MDN contributions play a significant role in the Bristol Bay region's productivity. However, the distribution and relative importance of the trophic subsidies provided by MDN within salmon-bearing watersheds are not expected to be spatially or temporally uniform (Janetski et al. 2009). MDN concentrations will be highest in areas of high spawning density and where carcasses accumulate. Adult salmon are found in

headwater streams of the SFK, NFK, and UTC watersheds, sometimes in extremely high numbers (Table 3-8); thus, MDN are likely contributing to the biological productivity of these headwaters and downstream habitats.

Where salmon are abundant, productivity of the Bristol Bay region's fish and wildlife species is highly dependent on this influx of MDN into the region's freshwater habitats (EPA 2014: Box 5-3). When and where available, salmon-derived resources—in the form of eggs, carcasses, and invertebrates that feed upon carcasses—are important dietary components for many fishes (e.g., juvenile Pacific salmon, Rainbow Trout, Dolly Varden, Arctic Grayling). Numerous studies have shown that the availability of MDN benefits stream-dwelling fishes via enhanced growth rate (Bilby et al. 1996, Wipfli et al. 2003, Giannico and Hinch 2007), body condition (Bilby et al. 1998), energy storage (Heintz et al. 2004), and ultimately increased chance of survival to reproductive age and adulthood (Gardiner and Geddes 1980, Wipfli et al. 2003, Heintz et al. 2004).

Eggs from spawning salmon are a major food source for Bristol Bay Rainbow Trout and are likely responsible for much of the growth attained by these fish and the abundance of trophy-sized Rainbow Trout in the Bristol Bay system. Scheuerell et al. (2007) reported that upon arrival of spawning salmon in the Wood River basin, Rainbow Trout shifted from consuming aquatic insects to primarily consuming salmon eggs, resulting in a five-fold increase in ration and energy intake. With this rate of intake, a bioenergetics model predicted a 3.5-ounce (100-g) trout would gain 2.9 ounces (83 g) in 76 days; without the salmon-derived subsidy, the same fish was predicted to lose 0.2 ounce (5 g) (Scheuerell et al. 2007). Rainbow Trout in Lower Talarik Creek, a stream immediately west of UTC, were significantly fatter (i.e., had a higher condition factor) in years with high salmon spawner abundance than in years with low abundance (Russell 1977).

Rainbow Trout are not the only fish species to benefit from these MDN subsidies. Research in Iliamna Lake suggests that between 29 percent and 71 percent of the nitrogen in juvenile Sockeye Salmon, and even higher proportions in other aquatic taxa, comes from MDN, and that the degree of MDN influence increases with escapement (Kline et al. 1993). In the Kvichak River, Dolly Varden move into ponds where Sockeye Salmon are spawning and experience three-fold higher growth rates when salmon eggs are available as a food source (Denton et al. 2009); Dolly Varden in the Iliamna River similarly rely heavily on MDN subsidies in the form of salmon eggs, carcasses, and associated invertebrates (Jaecks and Quinn 2014).

By dying in the habitats in which they spawn, adult salmon add their nutrients to the ecosystem that will feed their young and, thus, subsidize the next generation. In lakes and streams, MDN help to fuel the production of algae, bacteria, fungi, and other microorganisms that make up aquatic biofilms. These biofilms, in turn, provide food for aquatic invertebrates. MDN inputs are associated with increased standing stocks of macroinvertebrates (Claeson et al. 2006, Lessard and Merritt 2006, Walter et al. 2006), a primary food resource for juvenile salmon and other stream-dwelling fishes.

The importance of MDN to fish populations is perhaps most clearly demonstrated in cases where MDN supplies are disrupted by depletion of salmon populations. For example, prolonged depression of

salmon stocks in the Columbia River basin in Oregon has resulted in a chronic nutrient deficiency that hinders the recovery of endangered and threatened Pacific salmon stocks (Gresh et al. 2000, Petrosky et al. 2001, Achord et al. 2003, Peery et al. 2003, Scheuerell et al. 2005, Zabel et al. 2006) and diminishes the potential of expensive habitat improvement projects (Gresh et al. 2000). Density-dependent mortality has been documented among juvenile Chinook Salmon, despite the fact that populations have been reduced to a fraction of historical levels, suggesting that nutrient deficits have reduced the carrying capacity of spawning streams in the Columbia River basin (Achord et al. 2003, Scheuerell et al. 2005). Thus, diminished salmon runs can create a negative feedback loop, in which the decline in spawner abundance reduces the capacity of streams to produce new spawners (Levy 1997).

It is not just aquatic systems that benefit from these salmon-based MDN subsidies. Terrestrial mammals (e.g., Brown Bears, wolves, foxes, minks) and birds (e.g., Bald Eagles, waterfowl) also benefit from these subsidies (Brna and Verbrugge 2013, EPA 2014: Chapter 5; Armstrong et al. 2016). Alaskan Brown Bears aggregate and exhibit fidelity in their foraging of salmon in small streams in the Bristol Bay watershed (Wirsing et al. 2018). Availability and consumption of salmon-derived resources can have significant benefits for these species, including increased growth rate, energy storage, litter size, nesting success, and population density (Brna and Verbrugge 2013). In response to temporally shifting distributions of spawning Sockeye Salmon, species such as Brown Bears and gulls change their spatial distributions within the Bristol Bay watershed over the course of the summer (Schindler et al. 2013). Bears, wolves, and other wildlife also transport carcasses and excrete wastes throughout their ranges (Darimont et al. 2003, Helfield and Naiman 2006), thereby providing food and nutrients for other terrestrial species.

3.3.5 Commercial Fisheries

All five species of Pacific salmon are commercially harvested in Bristol Bay, across five fishing districts identified by specific rivers draining to the bay (Table 3-12). Sockeye Salmon dominate the region's salmon runs and harvest by a large margin (Table 3-12). Management of the Sockeye Salmon fishery in Bristol Bay is focused on discrete stocks (Section 3.3.3.2) (Tiernan et al. 2021), and the fishery's success depends on the conservation of biodiversity and sound, conservative management based on sustainable yields (ADF&G 2022d). Bristol Bay is home to the largest Sockeye Salmon fishery in the world, with 46 percent of the average global abundance of wild Sockeye Salmon between 1956 and 2005 (Ruggerone et al. 2010); between 2015 and 2019, Bristol Bay contributed 53 percent of global Sockeye Salmon production (McKinley Research Group 2021). Annual commercial harvest of Sockeye Salmon averaged 31.5 million fish between 2010 and 2019 (Table 3-12) (Tiernan et al. 2021). The 2021 commercial harvest of 40.4 million Sockeye Salmon was 44 percent higher than the recent 20-year average of 28.0 million for all districts (ADF&G 2021b). In 2021, 66.1 million Sockeye Salmon returned to Bristol Bay (ADF&G 2021b); this number increased by almost 20 percent in 2022, to 79.0 million—the largest inshore Sockeye Salmon run ever recorded in the region (ADF&G 2022e). More than half of the Bristol Bay watershed's Sockeye Salmon harvest comes from the Nushagak and Kvichak River watersheds (Table 3-12) (EPA 2014: Figure 5-9B).

Table 3-12. Mean annual commercial catch (number of fish) by Pacific salmon species and Bristol Bay fishing district, 2010–2019. Number in parentheses indicates percentage of total found in each district.

Salmon Species	Bristol Bay Fishing District					
	Naknek-Kvichak ^a	Egegik	Ugashik	Nushagak ^a	Togiak	TOTAL
Sockeye	10,737,106 (34)	7,595,433 (24)	3,439,233 (11)	9,059,705 (29)	636,660 (2)	31,468,532
Chinook	2,168 (7)	930 (3)	753 (2)	25,111 (76)	3,983 (12)	32,945
Coho	2,316 (2)	8,012 (6)	630 (2)	91,263 (72)	25,215 (18)	127,436
Chum	233,281 (22)	72,472 (7)	50,366 (5)	540,280 (51)	163,062 (15)	1,059,464
Pink ^b	12,362 (1)	1,972 (<1)	539 (<1)	802,849 (88)	94,282 (10)	912,004

Notes:

^a Naknek-Kvichak district includes the Alagnak River; Nushagak district includes the Wood and Igushik Rivers.

^b Pink Salmon data are from even-numbered years only; harvest is negligible during odd-year runs.

Source: Tiernan et al. 2021.

The Nushagak River watershed supported 72 percent of commercial Coho Salmon catch in the region between 2010 and 2019 (Table 3-12). Although Chinook Salmon is the least common salmon species across the Bristol Bay region, the Nushagak River watershed also supports a large Chinook Salmon fishery, and its commercial harvests are greater than those of all other Bristol Bay river systems combined (Table 3-12). Between 2010 and 2019, on average 76 percent of Bristol Bay's commercial Chinook Salmon catch came from the Nushagak fishing district (Table 3-12). Chinook Salmon returns to the Nushagak River are consistently greater than 100,000 fish per year and have exceeded 200,000 fish per year in 11 years between 1966 and 2010. This frequently places the Nushagak River at or near the size of the world's largest Chinook Salmon runs, which is notable given the Nushagak River's small watershed area compared to other Chinook-producing rivers (EPA 2014: Chapter 5).

Given the productivity of Pacific salmon, the commercial salmon fishery currently provides the Bristol Bay region's greatest source of economic activity, creating thousands of jobs and generating \$1 billion or more in economic output value through commercial fishing, processing, and support activities (Knapp et al. 2013, Wink Research and Consulting 2018, USACE 2020a, McKinley Research Group 2021). The McKinley Research Group (2021) estimates that in 2019, Bristol Bay's commercial fishery and related activities resulted in 15,000 jobs and an economic impact of \$2.0 billion, \$990 million of which was in Alaska. From 2000 through 2019, annual commercial salmon harvest in Bristol Bay averaged more than 27 million fishes across all five species (Tiernan et al. 2021). The annual ex-vessel commercial value⁴⁹ of this catch averaged \$147.9 million, \$146.4 million of which resulted from the Sockeye Salmon fishery (Table 3-13). In 2019, approximately 23 percent of Bristol Bay salmon permit holders were residents of the Bristol Bay watershed, and an additional 29 percent were residents of other areas in Alaska (McKinley Research Group 2021). This ex-vessel value translates to even higher wholesale values: for example, the 2010 Bristol Bay Sockeye Salmon harvest was worth \$165 million in direct harvest value and \$390 million in first wholesale value after processing (Knapp et al. 2013).

⁴⁹ Ex-vessel commercial value is the value paid to the fisher or permit holder upon delivery.

Table 3-13. Estimated ex-vessel value of Bristol Bay's commercial salmon catch by species, 2000–2019. Values are in thousands of dollars; number in parentheses indicates year that minimum or maximum value was obtained.

Salmon Species	Mean Value	Minimum Value (Year)	Maximum Value (Year)
Sockeye	146,372	31,962 (2002)	344,253 (2018)
Chinook	420	135 (2001)	1,240 (2006)
Coho	409	18 (2002)	1,990 (2014)
Chum	1,392	228 (2000)	2,891 (2018)
Pink ^a	436	0 (2002)	1,567 (2010)
TOTAL	147,874	32,544 (2002)	348,579 (2018)

Notes:

^a Pink Salmon data are from even-numbered years only; harvest is negligible during odd-year runs.

Source: Tiernan et al. 2021: Appendix A24.

3.3.6 Subsistence Fisheries

In the Bristol Bay region, the subsistence way of life is irreplaceable. Subsistence resources provide high-quality foods, foster a healthy lifestyle, and form the basis for social relations. Alaska Natives are the majority population in the Bristol Bay region, and salmon has been central to their health, welfare, and culture for thousands of years. In fact, Alaska Native cultures in the region represent one of the last intact salmon-based cultures in the world (EPA 2014: Appendix D). Much of the region's population—including both Alaska Natives and non-Alaska Natives—practices subsistence, with salmon making up a large proportion of subsistence diets. Thus, residents in this region are particularly vulnerable to potential changes in salmon resources (see Section 6.3 for discussion of tribal considerations, including environmental justice concerns).

There are 31 Alaska Native villages in the wider Bristol Bay region, 25 of which are located in the Bristol Bay watershed. Fourteen of these communities are within the Nushagak and Kvichak River watersheds, with a total population of 4,197 in 2020 (U.S. Census Bureau 2022). Dillingham (population 2,249) is the largest community; other communities range in size from four (year-round) residents (Portage Creek) to 512 residents (New Stuyahok). In some communities, the population increases during the subsistence fishing season. Thirteen of these 14 villages—all but Port Alsworth—have federally recognized tribal governments and had an Alaska Native population majority in 2020. No towns, villages, or roads are currently located in the SFK, NFK, and UTC watersheds. However, this area has been noted as important to the health and abundance of subsistence resources by traditional knowledge experts from communities in the area.

The following sub-sections discuss the use of subsistence fisheries in the region and its nutritional, cultural, and spiritual importance. Subsistence related to foods other than fish is discussed in Section 6.3.1.

3.3.6.1 Use of Subsistence Fisheries

Alaska Native populations of the Bristol Bay watershed, as well as non-Alaska Native residents, have continual access to a range of subsistence foods. As described by Fall et al. (2009), these subsistence resources are the most consistent and reliable component of local economies in the Bristol Bay

watershed, even given the world-renowned commercial fisheries and other recreational opportunities the region supports.

Virtually every household in the Nushagak and Kvichak River watersheds uses subsistence resources (EPA 2014: Appendix D, Table 12). No watershed-wide data are available for the proportion of residents' diets made up of subsistence foods, as most studies focus on harvest data and are not dietary surveys. However, data from 2014 indicate that the overall composition of wild food harvest in the Bristol Bay area is composed of 58 percent salmon, 20 percent land mammals (mostly moose and caribou), 9 percent other fishes, and 13 percent other sources (marine mammals, birds, eggs, marine invertebrates and wild plants) (Halas and Neufeld 2018). In 2004 and 2005, annual subsistence consumption rates in the Nushagak and Kvichak River watersheds were over 300 pounds per person in many villages and reached as high as 900 pounds per person (EPA 2014: Appendix D, Table 12).⁵⁰

Subsistence use varies throughout the Bristol Bay watershed, as villages differ in the per capita amount of subsistence harvest and the variety of subsistence resources used (Table 3-14). Salmon and other fishes are harvested throughout the Nushagak and Kvichak River watersheds (Figure 3-16) and provide the largest portion of subsistence harvests of Bristol Bay communities. On average, about 50 percent of the subsistence harvest by local community residents (measured in pounds usable weight) is Pacific salmon, and about 10 percent is other fishes (Fall et al. 2009). The percentage of salmon harvest in relation to all subsistence resources ranges from 29 percent to 82 percent in the villages (EPA 2014: Appendix D, Table 11); see Section 6.3.1 for further discussion of non-fish subsistence resources.

⁵⁰ For comparison, an average American consumes roughly 2,000 pounds of food per year.

Table 3-14. Harvest of subsistence fisheries resources in selected communities of the Bristol Bay watershed.

Community	Year	Total Harvest (pounds) ^a	Estimated Per Capita Harvest (pounds)				Households Using Salmon (%)		
			All Salmon	Sockeye Salmon	Chinook Salmon	Non-Salmon Fishes	Used	Gave	Received
Aleknagik	2008	51,738	143	40	72	26	100	59	59
Dillingham	2010	486,533	131	46	55	7	91	57	56
Ekwok	1987	77,268	456	160	180	68	93	48	52
Igiugig	2005	22,310	205	168	5	59	100	83	83
Iliamna	2004	34,160	370	370	0	34	100	31	39
Kokhanok	2005	107,644	513	480	3	36	97	63	60
Koliganek	2005	134,779	565	688	194	90	100	61	54
Levelock	2005	17,871	152	86	43	40	93	36	79
New Stuyahok	2005	163,927	188	36	113	28	90	55	63
Newhalen	2004	86,607	502	488	10	32	100	64	32
Nondalton	2004	58,686	219	219	0	34	92	55	63
Pedro Bay	2004	21,026	250	250	0	15	100	72	78
Port Alsworth	2004	14,489	89	88	1	12	100	46	55

Notes:

^a Total harvest values represent usable weight and include fishes, land mammals, freshwater seals, beluga, other marine mammals, plant-based foods, birds or eggs, and marine invertebrates. See Section 6.3.1 for additional information on non-fish subsistence resources.

Source: Schichnes and Chythook 1991 (Ekwok), Fall et al. 2006 (Iliamna, Newhalen, Nondalton, Pedro Bay, and Port Alsworth); Krieg et al. 2009 (Igiugig, Kokhanok, Koliganek, Levelock, New Stuyahok); Holen et al. 2012 (Aleknagik); Evans et al. 2013 (Dillingham).

Between 2008 and 2017, average annual subsistence salmon harvest in the Nushagak district was 49,024 fishes and in the Naknek-Kvichak district was 66,174 fishes (Halas and Neufeld 2018). There are differences in the relative importance of different subsistence fisheries between the two watersheds, however. Sockeye Salmon comprised 97 percent of this harvest in the Naknek-Kvichak district but only 53 percent in the Nushagak district, where Chinook Salmon (25 percent) and Coho Salmon (11 percent) were larger subsistence resources (Halas and Neufeld 2018). Villages along the Nushagak River (e.g., Ekwok, New Stuyahok) are particularly dependent on Chinook Salmon as a subsistence resource (Table 3-14), in part because Chinook Salmon are the first spawners to return each spring (EPA 2014: Appendix D). Between 2008 and 2017, average annual subsistence harvest of Sockeye Salmon ranged from 740 fish in Levelock to 27,755 fish in Dillingham (Table 3-15).

Table 3-15. Estimated subsistence salmon harvest in communities of the Bristol Bay watershed, 2008–2017. Values represent numbers of fish.

Community	Average Annual Subsistence Harvest of Salmon ^a	Minimum Annual Subsistence Harvest of Sockeye Salmon (Year)	Maximum Annual Subsistence Harvest of Sockeye Salmon (Year)
Aleknagik	2,623	1,570 (2010)	3,560 (2014)
Dillingham	27,755	22,037 (2012)	33,220 (2016)
Ekwok	1,849	1,253 (2012)	2,700 (2014)
Igiugig	1,346	345 (2013)	2,901 (2010)
Iliamna/Newhalen	10,564	6,403 (2017)	15,433 (2011)
Kokhanok	11,136	5,430 (2017)	16,530 (2012)
Koliganek	3,573	2,085 (2015)	7,290 (2013)
Levelock	740	30 (2008)	1,265 (2016)
New Stuyahok	6,727	5,062 (2012)	11,104 (2013)
Nondalton	7,215	2,320 (2016)	10,550 (2013)
Pedro Bay	3,742	1,678 (2017)	7,802 (2009)
Port Alsworth	4,024	3,155 (2009)	6,588 (2015)

Notes:

^a For communities in the Kvichak River watershed, number represents Sockeye Salmon harvest; for communities in the Nushagak River watershed, number represents all salmon species.

Source: Halas and Neufeld 2018.

All communities in the Nushagak and Kvichak River watersheds also rely on non-salmon fishes, including Northern Pike, various whitefish species, Dolly Varden, Arctic Char, and Arctic Grayling, but to a lesser extent than salmon. These fishes are taken throughout the year by a variety of harvest methods and fill an important seasonal component of subsistence cycles (Halas and Neufeld 2018). Non-salmon fishes are particularly important subsistence resources in spring and fall, when salmon and other resources are less available (Hazell et al. 2015). For example, in the mid-2000s, annual subsistence harvests for 10 communities in the Nushagak and Kvichak River watersheds were estimated at 3,450 Dolly Varden/Arctic Char (Alaska's fisheries statistics do not distinguish between the two species); 4,385 Northern Pike; and 7,790 Arctic Grayling (Fall et al. 2006, Krieg et al. 2009). Northern Pike were the most important non-salmon fishes in four of those villages during that time (Fall et al. 2006, Krieg et al. 2009). From the mid-1970s to the mid-2000s, Dolly Varden/Arctic Char, Northern Pike, and Arctic Grayling were estimated to represent roughly 16 to 27 percent, 10 to 14 percent, and 7

to 10 percent of the total weight of the Kvichak River watershed's non-salmon freshwater fish subsistence harvest, respectively (Krieg et al. 2005).

Although subsistence is a non-market economic activity that is not officially measured, the effort put into subsistence activities is estimated to be the same as or greater than full-time equivalent jobs in the cash sector (EPA 2014: Appendix E). There is a strong and complex relationship between subsistence and the market economy (largely commercial fishing and recreation) in the area (Wolfe and Walker 1987, Krieg et al. 2007). For example, income from the market economy funds household purchases of goods and services that are then used for subsistence activities (e.g., boats, rifles, nets, snowmobiles, and fuel). When Alaskan households spend money on subsistence-related supplies, the subsistence harvest of fishes generates regional economic benefits. In total, individuals in Bristol Bay communities harvest about 2.6 million pounds of subsistence foods per year (EPA 2014: Chapter 5). In 2010, the U.S. Census Bureau reported an estimated 1,873 Alaska Native and 666 non-Alaska Native households in the Bristol Bay region. Goldsmith et al. (1998) estimated that Alaska Native households spend an average of \$3,054 on subsistence harvest supplies, whereas non-Alaska Native households spend an estimated \$796 on supplies (values updated to 2009 price levels). Based on these estimates, subsistence harvest activities resulted in expenditures of approximately \$6.3 million (EPA 2014: Table 5-4).

The estimates above reflect only the annual economic activity generated by subsistence activities and not the value of the subsistence resources harvested. A study by the McKinley Research Group (2021) estimated that the replacement value of the 2017 Bristol Bay subsistence salmon harvest—that is, the cost of replacing subsistence salmon protein with store-bought substitutes—was between \$5 million and \$10 million (Table 3-16).

Table 3-16. Estimated replacement value of 2017 Bristol Bay subsistence salmon harvest.

Variable	Chinook	Chum	Coho	Pink	Sockeye	TOTAL
Number of fish	12,985	4,907	8,154	553	89,704	116,303
Pounds of usable fish	98,199	22,907	39,776	1,441	341,567	503,890
Species-specific % of total usable fish	19	5	8	0	68	100
Replacement value at \$10 per pound	\$981,992	\$229,066	\$397,762	\$14,411	\$3,415,673	\$5,038,904
Replacement value at \$20 per pound	\$1,963,980	\$458,140	\$795,524	\$28,820	\$6,831,346	\$10,077,800

Source: McKinley Research Group 2021.

3.3.6.2 Importance of Subsistence Fisheries

The salmon-dependent diet of Alaska Natives benefits their physical and mental well-being in multiple ways, in addition to encouraging high levels of fitness based on subsistence activities. Salmon and other traditional wild foods make up a large part of people's daily diets throughout their lives, beginning as soon as they are old enough to eat solid food (EPA 2014: Appendix D). Disproportionately high amounts of total diet protein and some nutrients come from subsistence foods. For example, a 2009 study of two rural Alaska regions found that 46 percent of protein, 83 percent of vitamin D, 37 percent of iron, 35 percent of zinc, 34 percent of polyunsaturated fat, 90 percent of eicosapentaenoic acid, and 93 percent of docosahexaenoic acid came from subsistence foods consumed by Alaska Natives (Johnson

et al. 2009). These foods have demonstrated nutritional benefits, including lower cumulative risk of nutritionally mediated health problems such as diabetes, obesity, high blood pressure, and heart disease (Murphy et al. 1995, Dewailly et al. 2001, Dewailly et al. 2002, Din et al. 2004, Hall et al. 2005, Chan et al. 2006, Ebbesson et al. 2007) and provision of essential micronutrients and omega-3 fatty acids (Murphy et al. 1995, Nobmann et al. 2005, Bersamin et al. 2007, Ebbesson et al. 2007). In addition, the cost of replacing subsistence salmon in diets, even with lower-quality protein sources, is likely to be significant (Table 3-16).

However, for Alaska Natives, subsistence is much more than the harvesting, processing, sharing, and trading of foods. Subsistence holistically subsumes the cultural, social, and spiritual values that are the essence of Alaska Native cultures (USACE 2020a: Section 3.9). Traditional and more modern spiritual practices place salmon in a position of respect and importance, as exemplified by the First Salmon Ceremony and the Great Blessing of the Waters (EPA 2014: Appendix D). The salmon harvest provides a basis for many important cultural and social practices and values, including the sharing of resources, fish camp, gender and age roles, and the perception of wealth. Tribal Elders and culture bearers continue to instruct young people, particularly at fish camps where cultural values, as well as fishing and fish processing techniques, are shared. The social system that forms the backbone of the culture, by nurturing the young, supporting the producers, and caring for the tribal Elders, is based on the virtue of sharing wild foods harvested from the land and waters.

The importance of salmon as a subsistence food source is inseparable from it being the basis for Alaska Native cultures. The characteristics of the subsistence-based salmon cultures in the Bristol Bay region have been widely documented (EPA 2014: Appendix D). The cultures have a strong connection to the landscape and its resources, and in the Bristol Bay watershed this connection has been maintained for centuries by the uniquely pristine condition of the region's landscape and resources. In turn, the respect and importance given salmon and other wildlife, along with Alaska Natives' traditional knowledge of the environment, have produced a sustainable, subsistence-based economy (EPA 2014: Appendix D). This subsistence-based way of life is a key element of Alaska Native identity and serves a wide range of economic, social, and cultural functions (USACE 2020a: Section 3.9).

3.3.7 Recreational Fisheries

In addition to commercial and subsistence fisheries, the Bristol Bay region also supports world-class recreational or sport fisheries. The Bristol Bay watershed (as reflected by the Bristol Bay Sport Fish Management Area, or BBMA) has been acclaimed for its sport fisheries, for fishes such as Pacific salmon, Rainbow Trout, Arctic Grayling, Arctic Char, and Dolly Varden, since the 1930s (Dye and Borden 2018). The uncrowded, pristine wilderness setting of the Bristol Bay watershed attracts recreational fishers, and aesthetic qualities are rated by Bristol Bay anglers as most important in selecting fishing locations (Duffield et al. 2007).

The importance of recreational fisheries can be estimated in several ways, including their economic value, the effort expended by recreational fishers, the number of fishes harvested, and the number of fishes caught (i.e., those harvested in addition to those caught and released).

Sport fishing in the Bristol Bay watershed accounts for approximately \$66.58 million in expenditures, expressed in 2020 dollars (USACE 2020a: Section 3.6). In 2009, approximately 29,000 sport-fishing trips were taken to the Bristol Bay region (12,000 trips by people living outside of Alaska, 4,000 trips by Alaskans living outside the Bristol Bay area, and 13,000 trips by Bristol Bay residents). These sport-fishing activities directly employ over 800 full- and part-time workers. In 2010, 72 businesses and 319 guides were operating in the Nushagak and Kvichak River watersheds alone, down from a peak of 92 businesses and 426 guides in 2008 (Rinella et al. 2018).

Between 2007 and 2017, angler-days of effort within the BBMA ranged from 74,560 to 102,844 annually, with total annual sport harvest for the same period ranging from 42,082 to 58,658 fishes (Dye and Borden 2018). Guided sport-fishing effort between 2007 and 2016 averaged 32,821 angler-days across the BBMA, of which approximately 7,059 and 1,704 angler-days were spent in the Nushagak River and Kvichak River watersheds, respectively (Dye and Borden 2018).

The majority of sport fishes harvested in the BBMA are Sockeye, Chinook, and Coho salmon, although Rainbow Trout, Dolly Varden, Arctic Char, and other species are also harvested throughout the BBMA (Table 3-17) (Dye and Borden 2018). The Nushagak and Kvichak River watersheds support several popular recreational fisheries, particularly for Sockeye and Chinook salmon (Figure 3-17), as well as Rainbow Trout. The Nushagak River watershed accounted for more than 50 percent of the annual average sport harvest (2004–2017) of Chinook Salmon in the BBMA, with an estimated harvest of 6,467 out of a total estimated harvest of 10,937 fish (Dye and Borden 2018); estimated recreational Chinook Salmon catches are much higher (Table 3-18). In the Kvichak River, recreational harvests are dominated by Sockeye Salmon, whereas recreational catches are dominated by Rainbow Trout.

Table 3-17. Estimated sport harvest by species in the Bristol Bay Sport Fish Management Area. Values are mean annual sport harvests from 2004 to 2017, and ranges observed during that same period. The years that the low and high values of each range were recorded are noted in brackets.

Fish	Mean Annual BBMA Sport Harvest ^a	Range
Sockeye Salmon	15,876	11,925 [2005]–23,842 [2017]
Chinook Salmon	10,836	6,224 [2010]–13,821 [2007]
Coho Salmon	15,682	12,380 [2013]–20,699 [2014]
Chum Salmon	1,627	501 [2007]–2,946 [2013]
Pink Salmon	805	47 [2009]–3,138 [2004]
Rainbow Trout	1,117	323 [2013]–2,411 [2007]
Dolly Varden/Arctic Char	2,498	1,040 [2013]–6,365 [2004]
Arctic Grayling	1,179	361 [2016]–3,010 [2004]
Lake Trout	759	188 [2012]–1,370 [2011]
Northern Pike	931	216 [2016]–1,751 [2004]

Notes:

^a BBMA = Bristol Bay Sport Fish Management Area.

Source: Dye and Borden 2018.

Figure 3-17. Popular areas for recreational fishing in the Nushagak and Kvichak River watersheds. Areas were digitized from previously published maps (Dye et al. 2006). Areas for recreational Rainbow Trout fishing are also distributed throughout the watersheds.

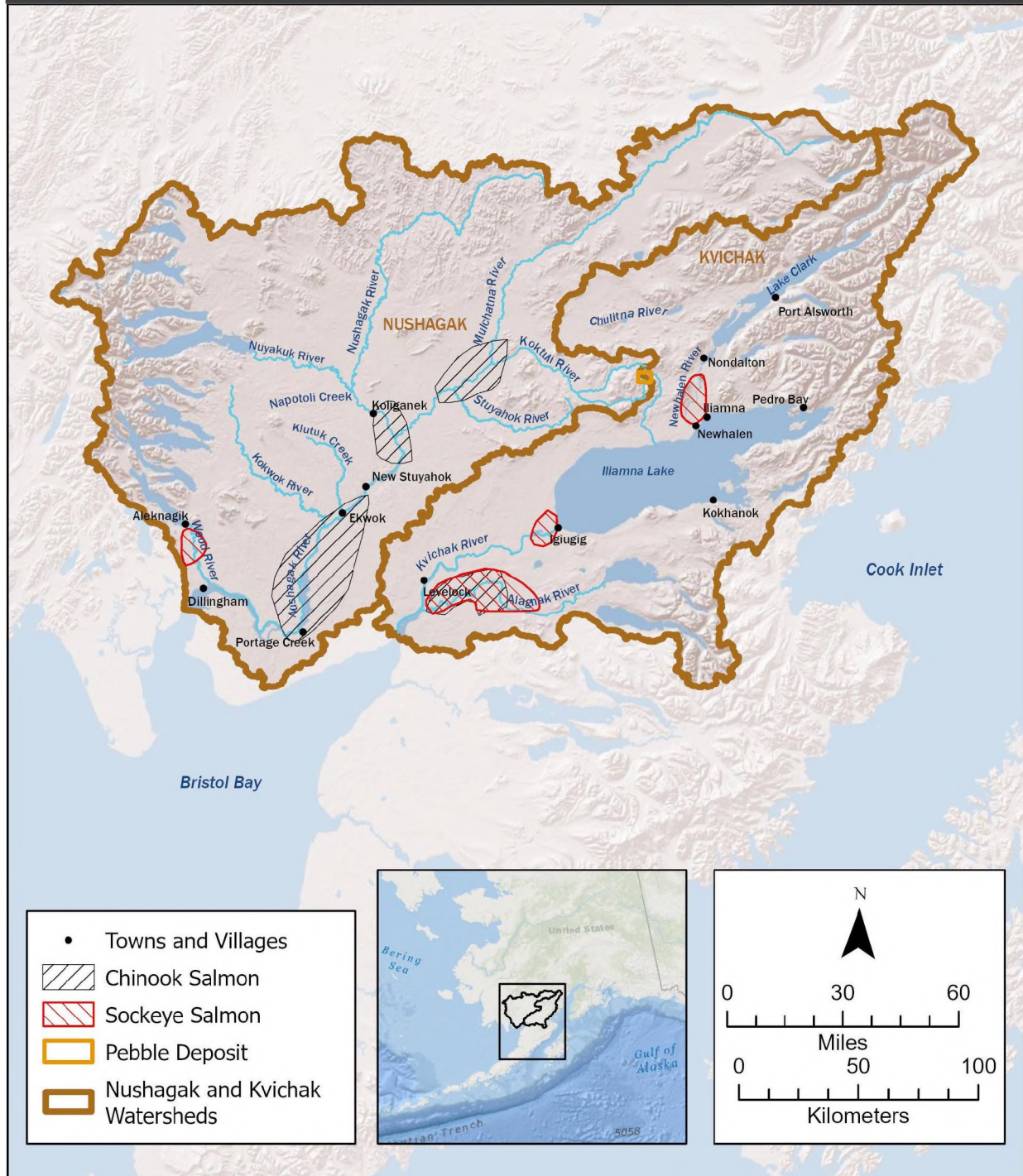


Table 3-18. Estimated annual sport harvest and catch of fishes in the Kvichak River watershed and the Nushagak, Wood, and Togiak River watersheds, 2008–2017. Estimated annual sport harvest is presented as the range between the minimum and maximum estimated annual harvest over the 2008–2017 period; estimated sport catch is shown for 2017.

Watershed	Fish	Estimated Annual Sport Harvest (Range, 2000–2010)	Estimated 2017 Sport Catch
Kvichak River	Pacific salmon ^a	7,199–14,731	56,492
	Sockeye	5,383–13,025	30,349
	Chinook	206–1,427	4,424
	Coho	342–676	9,138
	Chum	26–898	11,950
	Pink	10–625	631
	Rainbow Trout	48–996	114,431
	Dolly Varden/Arctic Char	46–605	16,239
	Arctic Grayling	84–757	18,695
	Lake Trout	124–856	2,224
	Northern Pike	11–547	1,938
	Whitefish	0–449	179
Nushagak, Wood, and Togiak River	Pacific salmon ^a	10,252–15,435	85,719
	Sockeye	1,598–5,504	12,514
	Chinook	4,514–9,283	31,631
	Coho	839–1,924	30,034
	Chum	561–2,560	9,216
	Pink	0–664	2,324
	Rainbow Trout	52–450	30,282
	Dolly Varden/Arctic Char	740–2,051	25,222
	Arctic Grayling	54–725	20,833
	Lake Trout	10–206	1,196
	Northern Pike	78–1,064	1,654
	Whitefish	0–514	602

Notes:

^a Total for all five Pacific salmon species (Coho, Chinook, Sockeye, Chum, Pink).

Source: Romberg et al. 2021.

3.3.8 Region's Fisheries in the Global Context

The Bristol Bay region is a unique environment supporting world-class fisheries, particularly in terms of Pacific salmon populations. Recent Sockeye Salmon returns to Bristol Bay highlight the region's productivity relative to other watersheds in the United States: the number of Sockeye Salmon that returned to Bristol Bay in 2022 (79.0 million)—more than 60 percent of which returned to the Nushagak and Naknek-Kvichak River watersheds—is roughly 20 million more than the number of individuals of all Pacific salmon species that historically returned annually to Washington, Oregon, and California before rivers in these states were dammed (Gresh et al. 2000, ADF&G 2022e). The region takes on even greater significance when one considers the status and condition of Pacific salmon populations throughout their native geographic distributions. These declines are discussed briefly below; for additional information on threatened and endangered salmon stocks, see Appendix A of the BBA (EPA 2014).

Although it is difficult to quantify the true number of extinct Pacific salmon populations around the North Pacific, estimates for the western United States (California, Oregon, Washington, and Idaho) range from 106 to 406 populations (Nehlsen et al. 1991, Augerot 2005, Gustafson et al. 2007). Pacific salmon are no longer found in 40 percent of their historical breeding ranges in the western United States, and populations tend to be significantly reduced or dominated by hatchery fishes where they do remain (NRC 1996). In contrast, Bristol Bay's salmon fisheries are robust and entirely wild, with no contribution from hatchery fishes in the watershed (Section 3.1).

For example, 214 salmon and Steelhead (anadromous Rainbow Trout) stocks were identified as facing risk of extinction in the western United States; 76 of those stocks were from the Columbia River basin alone (Nehlsen et al. 1991). In general, these losses have resulted from cumulative effects of habitat loss, water quality degradation, climate change, overfishing, dams, and other factors (NRC 1996, Schindler et al. 2010). Many watersheds that have historically supported large salmon runs, such as the Fraser River in Canada, are affected by multiple types of urban and industrial development, resulting in habitat loss and degradation and declines in salmon runs (O'Neal and Woody 2011, EPA 2014: Box 8-4). Species with extended freshwater rearing periods (e.g., Coho, Chinook, and Sockeye salmon) are more likely to be extinct, endangered, or threatened than species that spend less time in freshwater habitats (NRC 1996, Gustafson et al. 2007). No Pacific salmon populations from Alaska are known to have gone extinct, although many show signs of population declines.

The status of Pacific salmon throughout the United States highlights the value of the Bristol Bay watershed as a salmon sanctuary or refuge (Rahr et al. 1998, Pinsky et al. 2009). This value is likely to increase under changing climate conditions, which pose a key challenge for Pacific salmon conservation (Shanley and Albert 2014, Ebersole et al. 2020). Climate-associated changes in water temperature and streamflow, resulting changes in spawning and rearing habitats, responses of salmon populations, and the inherent uncertainties involved in predicting these relationships highlight the increasing importance of maintaining and protecting areas currently supporting diverse and robust salmon habitats and populations (Schindler et al. 2008, Anderson et al. 2015, Ebersole et al. 2020, Vynne et al. 2021).

The Bristol Bay watershed contains intact, connected, and heterogeneous habitats that extend from headwaters to ocean with minimal influence of human development. These characteristics, combined with the region's high Pacific salmon abundance and life-history diversity, make the Bristol Bay watershed a significant resource of global conservation value (Pinsky et al. 2009).

3.4 Summary

Because of its climate, geology, hydrology, largely undeveloped environment, and other characteristics, the Bristol Bay watershed is home to abundant, diverse, high-quality aquatic habitats. These streams, rivers, wetlands, lakes, and ponds support world-class subsistence, commercial, and recreational fisheries for multiple species of Pacific salmon, as well as numerous other fish species valued as subsistence and recreational resources. Because the region's salmon resources have supported Alaska Native cultures in the region for thousands of years and continue to support one of the last intact wild

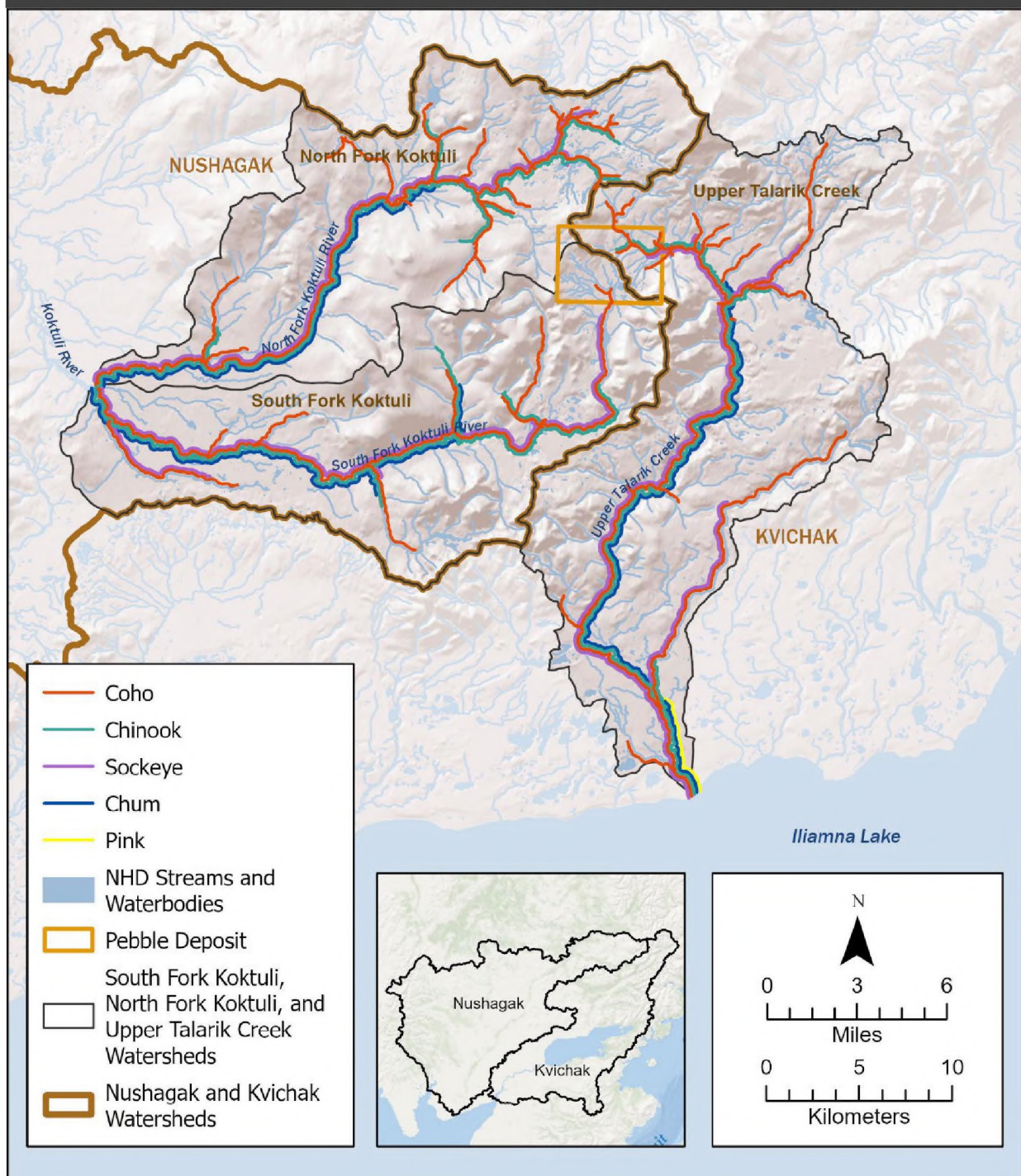
salmon-based cultures in the world (EPA 2014: Appendix D, Nesbitt and Moore 2016, USACE 2020a: Section 3.7), the watershed also has global cultural significance.

The productivity and diversity of the watershed's aquatic habitats are closely tied to the productivity and diversity of its wild fisheries, and waters of the SFK, NFK, and UTC watersheds are critical for maintaining the integrity, productivity, and sustainability of the region's salmon and non-salmon fishery resources. Aquatic habitats in the three watersheds are ideal for maintaining high levels of fish production with clean, cold water, gravel substrates, and abundant areas of groundwater exchange (upwelling and downwelling). These conditions create preferred salmon spawning habitat and provide favorable conditions for egg incubation and survival and juvenile rearing, and Pacific salmon species and life stages have been documented to occur, often in high numbers, throughout the three watersheds (Figure 3-18). They also provide high-quality habitat for other fishes, such as Rainbow Trout, Dolly Varden, Arctic Grayling, and Northern Pike. Wetlands and other off-channel areas provide essential habitats that protect young Coho Salmon and other resident and anadromous fish species, as well as provide spawning areas for Northern Pike. All of these species move throughout the region's freshwater habitats during their life cycles, and all are fished—commercially, for subsistence use, and recreationally—in downstream waters. Thus, the intact headwater-to-larger river systems found in the SFK, NFK, and UTC watersheds, with their associated wetlands, lakes, and ponds, help sustain the overall productivity of these fishery areas.

Not only do the aquatic habitats of the SFK, NFK, and UTC watersheds directly provide habitat for salmon and other fishes, they also provide critical support for downstream habitats. By contributing water, organic matter, macroinvertebrates, and other materials to downstream systems, these headwater areas help maintain downstream habitats and fuel their fish productivity. Together, these functions—direct provision of high-quality habitat and indirect provision of other resources to downstream habitats—help support the valuable fisheries of the Bristol Bay watershed.

This support is particularly important in terms of Coho, Chinook, and Sockeye salmon fisheries. Chinook Salmon are the rarest of the North American Pacific salmon species and are a critical subsistence resource, particularly along the Nushagak River. The SFK, NFK, and UTC watersheds are known to support small, discrete populations of Sockeye Salmon that are genetically programmed to return to specific, localized reaches or habitats to spawn. The current state of understanding surrounding Pacific salmon genetic baselines in the region indicates that the watersheds also support small, discrete populations of Coho Salmon and Chinook Salmon. These portfolios of multiple small populations, which exist as a result of the region's habitat complexity, are essential for maintaining the genetic diversity, and thus the stability and productivity, of the region's overall wild salmon stocks.

Figure 3-18. Streams, rivers, lakes, and documented salmon use in the South Fork Koktuli River, North Fork Koktuli River, and Upper Talarik Creek watersheds near the Pebble deposit. Species distributions are based on the Anadromous Waters Catalog (Giefer and Graziano 2022).



SECTION 4. BASIS FOR FINAL DETERMINATION

Starting with an analysis of the 2020 Mine Plan, this section provides EPA's evaluation regarding how certain discharges of dredged or fill material into certain waters of the United States associated with developing a mine at the Pebble deposit will have unacceptable adverse effects on anadromous fishery areas (including spawning and breeding areas).

Section 4.1 presents a brief review of the CWA Section 404(c) Standards. Section 4.2 provides the unacceptability findings that support the prohibition and restriction described in Section 5. Section 4.3 provides an overview of EPA's evaluation of the effects of discharges associated with developing a mine at the Pebble deposit, such as the 2020 Mine Plan, under the relevant portions of the CWA Section 404(b)(1) Guidelines (40 CFR Part 230). Section 4.4 provides an alternative basis for EPA's determination, which includes additional considerations such as EPA's consideration of costs as described below.

4.1 CWA Section 404(c) Standards

The purpose of the CWA is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (33 U.S.C. 1251(a)). The CWA sets several goals, including attainment and preservation of "water quality which provides for the protection and propagation of fish, shellfish and wildlife" (33 U.S.C. 1251(a)(2)).

To this end, CWA Section 404(c) specifically authorizes EPA to exercise its discretion to act "whenever" it determines that the discharge of dredged or fill material will have an unacceptable adverse effect on specific aquatic resources. CWA Section 404(c) provides the following:

The Administrator is authorized to prohibit the specification (including the withdrawal of specification) of any defined area as a disposal site, and he is authorized to deny or restrict the use of any defined area for specification (including the withdrawal of specification) as a disposal site, whenever he determines, after notice and opportunity for public hearings, **that the discharge of such materials into such area will have an unacceptable adverse effect on municipal water supplies, shellfish beds and fishery areas (including spawning and breeding areas), wildlife, or recreational areas.** Before making such determination, the Administrator shall consult with the Secretary. The Administrator shall set forth in writing and make public his findings and his reasons for making any determination under this subsection. [33 USC 1344(c)] [emphasis added]

Importantly, CWA Section 404(c) specifically directs EPA to consider adverse effects from the discharge of dredged or fill material to fishery areas, including spawning and breeding areas. As a scientific matter, evaluating adverse effects to fishery areas (e.g., fish habitat) involves consideration of numerous factors, including adverse effects that discharges of dredged or fill material can directly have on aquatic areas where fish occurrence has been documented, as well as the adverse effects such discharges can have on

aquatic areas that provide ecosystem functions and values that support fishery areas. Therefore, this section includes discussion of these considerations.

CWA Section 404(c) does not define the term “unacceptable adverse effect.” EPA’s regulations at 40 CFR 231.2(e) define “unacceptable adverse effect” as:

[I]mpact on an aquatic or wetland ecosystem which is likely to result in significant degradation of municipal water supplies (including surface or ground water) or significant loss of or damage to fisheries, shellfishing, or wildlife habitat or recreation areas. In evaluating the unacceptability of such impacts, consideration should be given to the relevant portions of the Section 404(b)(1) Guidelines (40 CFR Part 230).⁵¹

The preamble to EPA’s final rule promulgating 40 CFR Part 231 further explained that “[t]he term ‘unacceptable’ in EPA’s view refers to the significance of the adverse effect – ‘e.g., is it a large impact and is it one that the aquatic ecosystem cannot afford.’ (44 FR 58076, 58078).

EPA’s determination of an “unacceptable adverse effect” necessarily involves a case-by-case determination based on many factors, including the unique characteristics of the aquatic resource that would be affected by discharges of dredged or fill material. EPA defines “unacceptable adverse effect” to mean an “impact on an aquatic or wetland ecosystem *which is likely to result in ... significant loss of or damage to fisheries, shellfishing, or wildlife habitat*” 40 CFR 231.2(e) (emphasis added). EPA’s preamble to the CWA Section 404(c) regulations explained that “[b]ecause 404(c) determinations are by their nature based on predictions of future impacts, what is required is a reasonable likelihood that unacceptable adverse effects will occur – not absolute certainty but more than mere guesswork” (44 FR 58078).⁵²

Finally, EPA’s consideration of “unacceptable adverse effects” on the enumerated statutory resources (e.g., fishery areas) may include adverse effects on those resources within the defined area or adverse effects on such resources in areas downstream of the defined area. *See Mingo Logan Coal Co. v. U.S. EPA*, 70 F. Supp. 3d 151, 177-180 (D.D.C., 2014) (holding that “EPA may consider downstream effects when conducting its section 404(c) unacceptable adverse effects analysis.”); *aff’d Mingo Logan Coal. Co. v. U.S. EPA*, 829 F.3d 710, 725-26 (D.C. Cir 2016) (concluding “that, as part of EPA’s overall authority, section 404(c) authorizes it to assess the effects of the fill beyond the fill’s footprint”).

The EPA Assistant Administrator for Water has prepared this final determination because she has determined that certain discharges of dredged or fill material into certain waters of the United States

⁵¹ The language referring to “municipal water supplies, shellfish beds and fishery areas (including spawning and breeding areas), wildlife, or recreational areas” in Section 404(c) of the CWA is synonymous with the references in 40 CFR 231.2 to “municipal water supplies (including surface or ground water)” and “fisheries, shellfishing, or wildlife habitat or recreation areas.”

⁵² In fact, EPA’s 404(c) regulations include different standards throughout the process to reflect that EPA’s certainty regarding its unacceptable adverse effect determination builds as the record develops (i.e., from unacceptable adverse effect “could result” at the early proposed determination stage to using “would” at the later stages). The preamble to the final CWA Section 404(c) regulations explained “[w]hile EPA has used the word ‘would’ for the later stages in the proceedings, to reflect the statutory language, it is important to note that absolute certainty is not required.” 44 FR 58078.

associated with developing the Pebble deposit will have unacceptable adverse effects on anadromous fishery areas. These effects are described in detail in Section 4.2.

4.2 Effects on Fishery Areas from Discharges of Dredged or Fill Material from Developing the Pebble Deposit

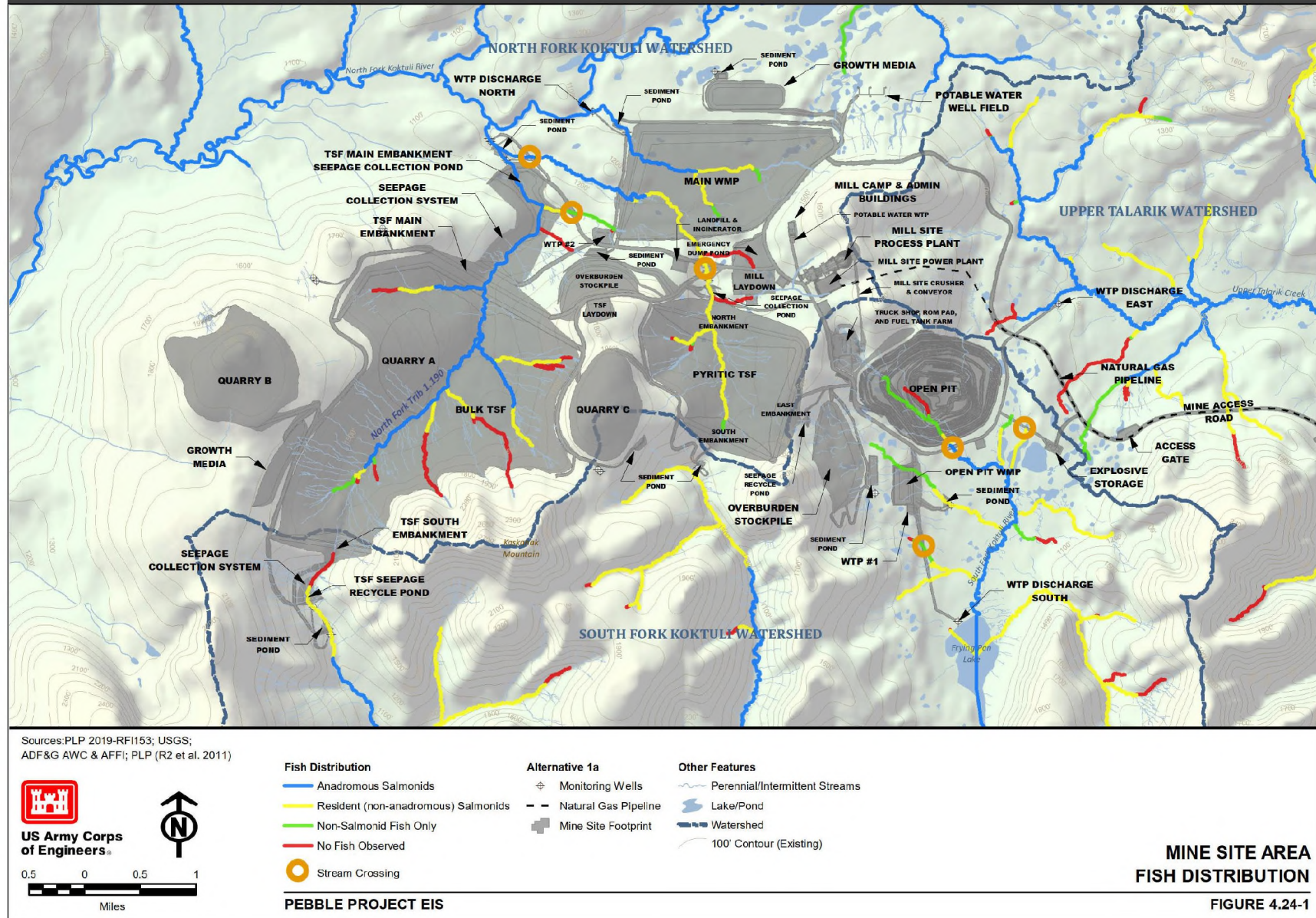
Development of a mine at the Pebble deposit is expected to require the discharge of dredged or fill material into waters of the United States due to current mining technology and the high density of water resources around the Pebble deposit. For example, development of the 2020 Mine Plan would require the discharge of dredged or fill material into waters of the United States at the mine site (PLP 2020b, USACE 2020a, USACE 2020b).

According to the FEIS for the 2020 Mine Plan, “no other wild salmon fishery in the world exists in conjunction with an active mine of this size” (USACE 2020a: Page 4.6-9). As discussed in Section 3, the Bristol Bay watershed is an outstanding global resource, providing pristine, intact, connected aquatic habitats from headwaters to ocean. These aquatic habitats provide extensive spawning and rearing areas for and support genetically diverse populations of wild salmon. Like the larger Bristol Bay watershed, the SFK, NFK, and UTC watersheds also contain pristine, intact aquatic habitats that provide extensive spawning and rearing areas for and support genetically diverse populations of wild salmon.

EPA also recognizes the 2020 Mine Plan represents only one configuration of a potential mine at the Pebble deposit, and any relocation of mine site components to other areas would result in discharges of dredged or fill material to water resources within and beyond the mine site area delineated in the 2020 Mine Plan (Figure 4-1).

EPA has evaluated the adverse effects of discharges of dredged or fill material associated with development of the Pebble deposit on anadromous fishery areas in the SFK, NFK, and UTC watersheds. EPA has evaluated these adverse effects at the scale of the SFK, NFK, and UTC watersheds because these watersheds are the areas that would be most directly affected by discharges of dredged or fill material associated with the development of a mine at the Pebble deposit and because the most extensive physical, chemical, and biological data currently available have been collected in these watersheds (e.g., PLP 2011, PLP 2018a, USACE 2020a). Evaluating the effects of discharges of dredged or fill material for the construction and routine operation of a mine at the Pebble deposit at the scale of the SFK, NFK, and UTC watersheds also enables EPA to draw conclusions at the spatial and temporal scales that are most biologically relevant to the species (salmon) and life stages (eggs, juveniles, adults) of concern—that is, the spatial and temporal scales that ultimately determine the reproductive success and long-term persistence of these species and their genetically distinct populations.

Figure 4-1. Mine site area fish distribution. Figure 4.24-1 from the FEIS (USACE 2020a: Section 4.24).



This section considers both the direct and secondary effects of such discharges on anadromous fishery areas. Direct effects are impacts on aquatic resources associated with the discharge (actual placement) of dredged or fill material into waters of the United States. Direct adverse effects of the 2020 Mine Plan would include elimination of streams and other aquatic resources within the footprints of the mine site components (e.g., TSFs, WMPs, stockpiles, and the open pit).

Secondary effects are associated with the discharge of dredged or fill material, but do not result from actual placement of this material [40 CFR 230.11(h)(1)]. Secondary effects “are an important consideration in evaluating the acceptability of a discharge site” under the CWA Section 404(b)(1) Guidelines (45 FR 85343).

Direct and secondary (indirect) effects evaluated in the FEIS include the following (USACE 2020a: Section 4.22.3):

- Direct effects from:
 - Clearing and removal of vegetation
 - Excavation or removal of soil and vegetation
 - Placement of fill materials
 - Dredging and discharges of dredged materials
 - Alteration and removal of stream channels
- Secondary effects from:
 - Fragmentation of aquatic resources
 - Fugitive dust
 - Downstream habitat degradation
 - Dewatering

The direct and secondary adverse effects of the discharge of dredged or fill material for the construction and routine operation of the 2020 Mine Plan include both the permanent loss of certain aquatic resources and the degradation of and, thus, damage to additional aquatic resources. For the purposes of this final determination, aquatic resource losses result from elimination, dewatering, and fragmentation (Box 4-1 and Box 4-2).

BOX 4-1. SECONDARY EFFECTS AND AQUATIC RESOURCE LOSSES

Secondary effects are associated with the discharge of dredged or fill material, but do not result from actual placement of this material (40 CFR 230.11(h)(1)). Severity of these secondary effects depends on factors such as the type of aquatic resource being impacted, the type of impact, and the duration of the impact. When sufficiently severe, these secondary effects of the discharge of dredged or fill material can result in the loss of aquatic resources. For example, in certain circumstances, secondary effects such as habitat fragmentation and dewatering can result in aquatic resource losses.

Fragmentation of streams, wetlands, and other waters results when development divides a formerly continuous aquatic resource into smaller, more isolated remnants. Effects of fragmentation on streams, wetlands, and other waters are wide-ranging and depend on several factors, including the nature of the development; the size, shape, and complexity of the remnants; the hydrogeomorphology and community composition of the affected habitat; and the needs and mobility of fish and wildlife species that depend on the affected habitats. Decreased connectivity of aquatic ecosystems could preclude the completion of aquatic organisms' life cycles; for example, fragmentation could prevent anadromous fishes from reaching spawning grounds or accessing off-channel habitat (USACE 2020a: Section 4.22). For anadromous fishes, the most severe form of fragmentation occurs when discontinuities are created that either (1) separate an aquatic habitat (stream, wetland, lake, pond) or complex of aquatic habitats from the tributary network in such a way that precludes use (e.g., spawning, rearing, feeding, migration, overwintering) by anadromous fish species and life stages documented to occur in the habitat, or (2) eliminate the movement of water or dissolved or suspended materials to downstream anadromous fish streams. This type of fragmentation represents a loss for anadromous fishes when it persists for 5 or more years, because such a time period reflects the typical life cycle of anadromous fishes (Brazil and West 2016) that are discussed in this final determination.

Dewatering of streams, wetlands, and other aquatic resources causes the alteration or loss of hydrology and may result in the conversion of habitat to more mesic types. Under the 2020 Mine Plan, groundwater drawdown can extend beyond half of a mile in some areas, but is expected primarily around the open pit from dewatering activities, as well as around quarries, TSFs, and WMPs from diversions and drainage/underdrain systems. Altered saturated surface flows and shallow interflows resulting from a depression of the groundwater table are expected to permanently affect area wetlands, surface waters, and vegetation. The severity of impact will depend on a number of factors, including aquatic resource type, hydrogeomorphology, and community composition (USACE 2020a: Section 4.22). For anadromous fishes, the most severe effects of dewatering for each aquatic resource type are as follows:

- For documented anadromous waters, removing sufficient flow to eliminate access to or use of habitat for the species and life stages documented to occur in the reach in question;
- For additional streams, removing sufficient flow to eliminate the downstream movement of water or dissolved or suspended materials;
- For ponds or lakes, reducing the spatial extent of the pond or lake; and
- For wetlands, changing the hydrologic regime such that the wetland no longer exhibits wetland hydrology, as defined in the *Corps of Engineers Wetland Delineation Manual* (USACE 1987).

These effects of dewatering represent a loss for anadromous fishes when they persist for 5 or more years, because such a time period reflects the typical life cycle of anadromous fishes (Brazil and West 2016) that are discussed in this final determination.

BOX 4-2. KEY DEFINITIONS

The following definitions are provided to clarify key terms in this final determination.

Anadromous fishes hatch in freshwater habitats, migrate to sea for a period of relatively rapid growth, and then return to freshwater habitats to spawn. For the purposes of this final determination, "anadromous fishes" refers to Coho or Silver salmon (*Oncorhynchus kisutch*), Chinook or King salmon (*O. tshawytscha*), Sockeye or Red salmon (*O. nerka*), Chum or Dog salmon (*O. keta*), and Pink or Humpback salmon (*O. gorbuscha*). For these five species of Pacific salmon, the majority of surviving adults return to their natal freshwater habitats to spawn. This homing behavior fosters reproductive isolation, thereby enabling populations to adapt to the specific environmental conditions of their natal habitats (Section 3.3.3). Each of these species is semelparous: adults die after spawning a single time (representing a single opportunity to pass on their genes), thereby depositing the nutrients incorporated in their body mass into their spawning and rearing habitats (Section 3.3.4).

Documented anadromous fish occurrence means any use by Coho, Chinook, Sockeye, Chum, or Pink salmon. As a general matter, EPA has relied on the Catalog of Waters Important for the Spawning, Rearing or Migration of Anadromous Fishes (Giefer and Blossom 2021, ADF&G 2022b, Giefer and Graziano 2022) and its associated Atlas to describe use by the five salmon species. The catalog and atlas identify the streams, rivers, and lakes specified by the Alaska Department of Fish and Game as important for the spawning, rearing, or migration of anadromous fish pursuant to AS 16.05.871.

Additional streams that support anadromous fish streams refers to streams that do not have documented anadromous fish occurrence but that support downstream anadromous fish streams. Although such streams may also be used by anadromous fishes (see also Section 4.2.2 and Appendix B), the potential for such use is not a basis for this final determination. These aquatic resources are identified as *stream habitat* in the FEIS.

Loss, as in loss of streams, wetlands, or other waters, can result either directly from the discharge of dredged or fill material for the construction and routine operation of a mine to develop the Pebble deposit or indirectly from the secondary effects of such discharges. A loss would result in the following effects for 5 years or more:

- Elimination of streams, wetlands, or other waters within the footprints of mine site components (e.g., TSFs, WMPs, stockpiles, roads, and the open pit);
- Dewatering (see definition below); or
- Fragmentation, meaning creation of discontinuities that separate an aquatic habitat (stream, wetland, lake, pond) or complex of aquatic habitats from the tributary network in such a way that either precludes use (e.g., spawning, rearing, feeding, migration, overwintering) by anadromous fish species and life stages documented to occur in the habitat or eliminates the downstream movement of water or dissolved or suspended materials.

Dewatering includes

- For documented anadromous waters, removing sufficient flow to eliminate access to or use of habitat for the anadromous fish species and life stages documented to occur in the reach in question;
- For additional streams, removing sufficient flow to eliminate the downstream movement of water or dissolved or suspended materials;
- For ponds or lakes, reducing the spatial extent of the pond or lake; and
- For wetlands, changing the hydrologic regime such that the wetland no longer exhibits wetland hydrology, as defined in the *Corps of Engineers Wetland Delineation Manual* (USACE 1987).

Section 4.2 considers the following impacts from the discharge of dredged or fill material for the construction and routine operation of the 2020 Mine Plan:

- The loss of approximately 8.5 miles (13.7 km) of documented anadromous fish streams⁵³ (Section 4.2.1).
- The loss of approximately 91 miles (147 km) of additional streams that support anadromous fish streams (Section 4.2.2).⁵⁴
- The loss of approximately 2,108 acres (8.5 km²) of wetlands and other waters that support anadromous fish streams (Section 4.2.3).⁵⁵
- Adverse impacts on approximately 29 additional miles (46.7 km) of documented anadromous fish streams resulting from greater than 20 percent changes in average monthly streamflow (Section 4.2.4).

Sections 4.2.1 through 4.2.4 describe the basis for EPA's determination that each of these losses or streamflow changes independently will have unacceptable adverse effects on anadromous fishery areas (including spawning and breeding areas) in the SFK and NFK watersheds. Because the 2020 Mine Plan represents only one configuration of a potential mine to develop the Pebble deposit,⁵⁶ Sections 4.2.1 through 4.2.4 also evaluate the adverse effects of these levels of loss and streamflow changes resulting from discharges of dredged or fill material associated with developing the Pebble deposit, if they occur elsewhere in the mine site area (Figure 4-1) within the SFK and NFK watersheds or anywhere in the SFK, NFK, and UTC watersheds.

As discussed in Sections 4.2.1 through 4.2.4, EPA has also determined that discharges of dredged or fill material associated with developing the Pebble deposit anywhere in the mine site area that would result in the same or greater levels of loss or streamflow changes as the 2020 Mine Plan will have unacceptable adverse effects on anadromous fishery areas because such discharges would involve the same aquatic resources characterized in the evaluation of the 2020 Mine Plan.

Furthermore, the SFK, NFK, and UTC watersheds share several similarities in characteristics and aquatic resources, including similarities in the types and abundance of aquatic habitats, their general physical and chemical characteristics, and the organisms that use those habitats (Box 3-1). As discussed in Sections 4.2.1 through 4.2.4, these similarities provide support for EPA's determination that, if the levels of loss and streamflow changes identified for the 2020 Mine Plan occurred anywhere in the SFK, NFK,

⁵³ For the purposes of this final determination, anadromous fishery areas include anadromous fish streams.

⁵⁴ This value has been rounded in this final determination to address differences in rounding of stream length information in different parts of the FEIS (USACE 2020a).

⁵⁵ This value changed from the proposed determination to reflect only losses of wetlands and other waters in the SFK and NFK watersheds, which are a particular focus of Section 4.2.3.

⁵⁶ Given current mining technology and the high density of water resources in the area, the discharge of dredged or fill material into waters of the United States is expected to be necessary to develop the Pebble deposit.

and UTC watersheds, those losses and streamflow changes also will have unacceptable adverse effects on anadromous fishery areas in these watersheds.

In making its unacceptable adverse effects determinations, EPA considered adverse effects on anadromous fishery areas within the defined areas and downstream of the defined areas. In Sections 4.2.1 through 4.2.4, EPA explains its basis for concluding that the impacts of the discharges evaluated in this final determination on the aquatic or wetland ecosystems are likely to result in significant loss of or damage to fisheries (i.e., fishery areas, including breeding or spawning grounds) and that the significance of the adverse effects are unacceptable (i.e., why EPA considers the impacts “large” and ones “that the aquatic and wetland ecosystem cannot afford”) (44 FR 58078).

4.2.1 Adverse Effects of Loss of Anadromous Fish Streams

EPA has determined that the discharge of dredged or fill material for the construction and routine operation of the 2020 Mine Plan, resulting in the loss of approximately 8.5 miles (13.7 km) of anadromous fish streams, will have unacceptable adverse effects on anadromous fishery areas in the NFK watershed. As discussed in Section 4.2.1, this conclusion is based on the permanent loss of anadromous fish streams.⁵⁷ The permanent loss of 8.5 miles (13.7 km) of anadromous fish streams in the NFK watershed represents a significant loss of anadromous fishery areas and the permanent loss of ecological subsidies these anadromous fish streams provide to downstream anadromous fish streams represents significant damage to these downstream anadromous fishery areas.

4.2.1.1 Extent of Anadromous Fish Streams That Would Be Permanently Lost at the Mine Site

Streams in the mine site area for the 2020 Mine Plan were evaluated in detail and several were found to provide habitat for anadromous fishes (Figure 4-1). Discharges of dredged or fill material associated with the 2020 Mine Plan would result in the permanent loss of approximately 8.5 miles (13.7 km) of streams with documented anadromous fish occurrence, specifically occurrence of Coho and Chinook salmon (Table 4-1, Figure 4-2) (PLP 2020b, USACE 2020a: Section 4.24, Giefer and Graziano 2022). The loss of all 8.5 miles (13.7 km) would be confined to the NFK watershed, specifically to Tributary NFK 1.190, Tributary NFK 1.200, and their sub-tributaries (Figure 4-2). The loss of 8.5 miles (13.7 km) of anadromous fish streams represents approximately 13 percent of the anadromous fish streams in the NFK watershed (USACE 2020a: Section 4.24, Giefer and Graziano 2022).

⁵⁷ These permanent losses are the result of streams filled or otherwise eliminated for the construction of various mine components and from streams that would no longer be accessible to fishes due to mine site infrastructure (i.e., fragmentation).